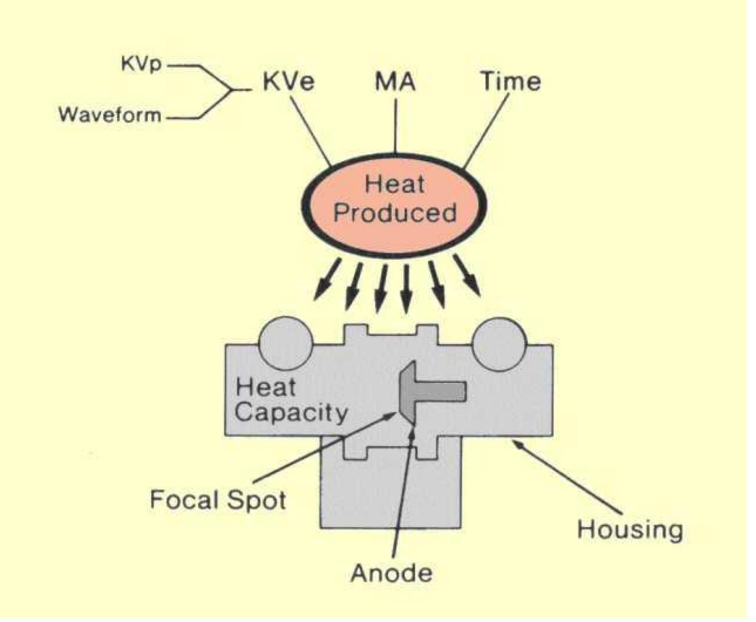
Tube Ratings



- If excessive heat is produced in the x-ray tube, the temperature will rise above critical values, and the tube can be damaged. This damage can be in the form of melted anode.
- In order to prevent this damage, the x-ray equipment operator must be aware of the quantity of **heat produced** and its relationship to the **heat capacity** of the x-ray tube.

Tube loading

Amount of Heat produced in the focal spot area by the bombarding electrons from the cathode.

1) Tube loading by joules:

Tube loading (J) = KV_e x mAS (in joules)

or

Tube loading (J) = w x KV_p x mAS.

KV_e is the effective KV value

KV_p is the peak **KV** value.

w is the waveform factor; its value is determined by the waveform e.g. constant potential, 1.0; three-phase, 0.99; single-phase, 0.71.

2) Tube loading by heat unit (HU):

Used as alternative for joule to calculate tube loading when single-phase equipment is used.

HU = 1.4 x tube loading by joule

$= 1.4 \times 0.7 \times KV_p \times mAS$.

$= KV_p \times mAS$.

3) Tube power:

The **rate** at which heat is produced in a tube

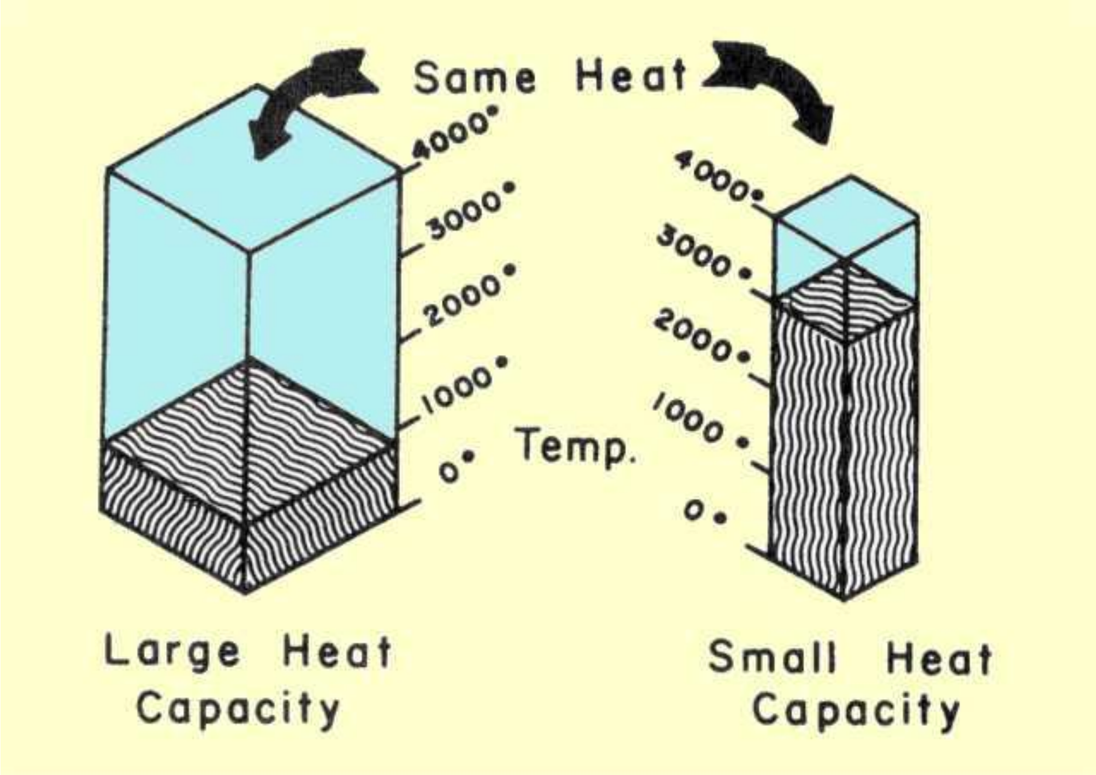
Power = $w \times KV_p \times mA$ (watts = j/s)

= joules / exposure time

HEAT CAPACITY= tube rating

- Temperature of tube = heat produced (J) / heat capacity.
- When a given amount of heat is added, the temperature increase is inversely proportional to the heat capacity.
- The goal is never to exceed specific **critical temperatures** by keeping the heat produced below specified critical values (specific to each tube according to its heat capacity).

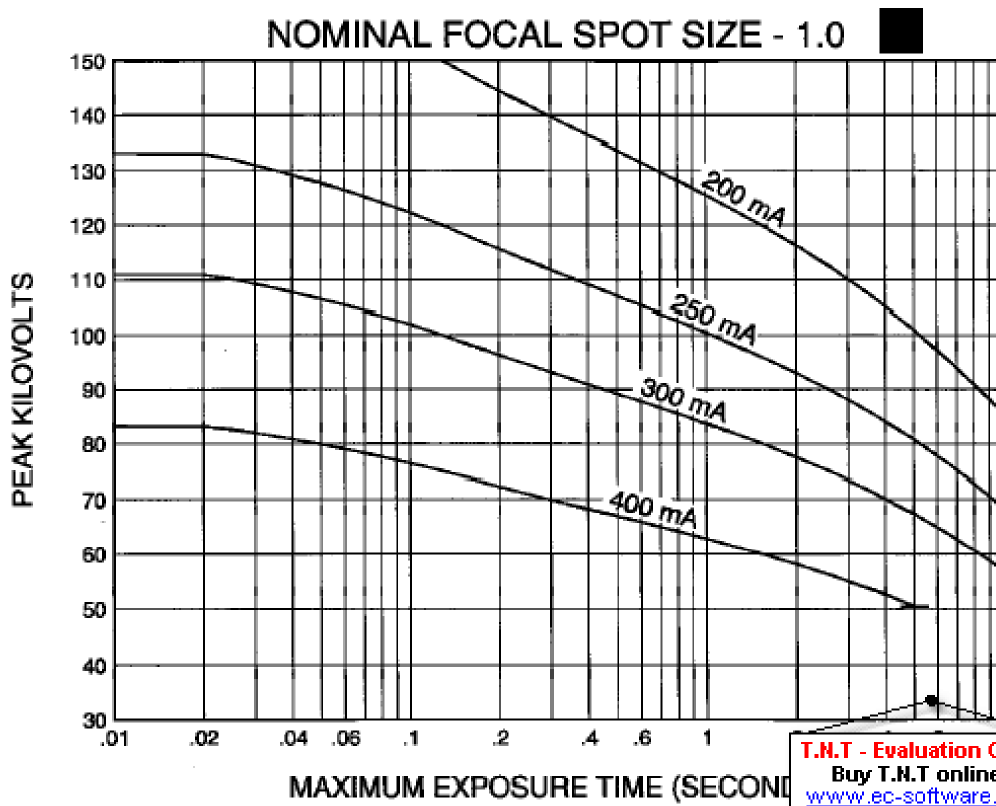
If the quantity of heat delivered during an individual exposure exceeds the heat capacity, the anode surface can melt



1) Tube rating for single radiographic exposure:

- The capacity is generally specified by the manufacturer in the form of a graph
- The curves on the graph show the maximum power (KV and mA) that can be delivered to the tube for a given exposure time without producing overload
- Tube rating is expressed as allowable mA

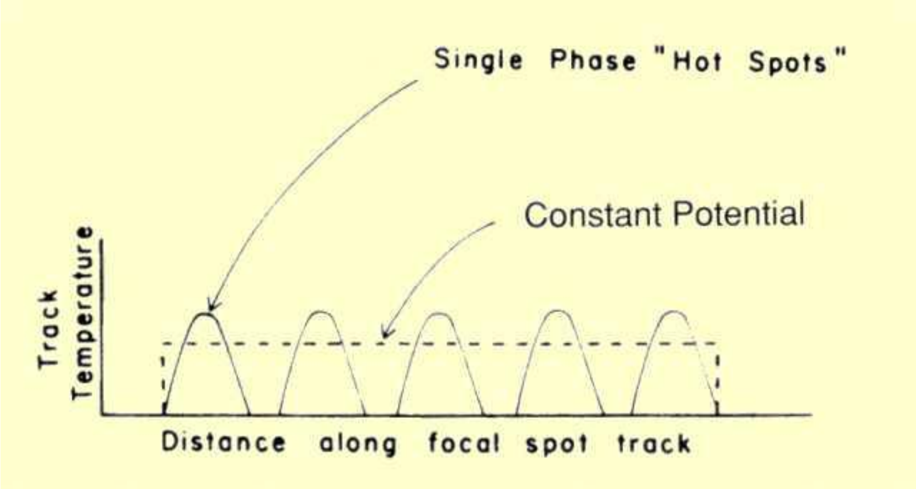
Note that :
1)Allowable mA is decreased with increasing exposure time
2)Allowable mAs is increased with increasing exposure time

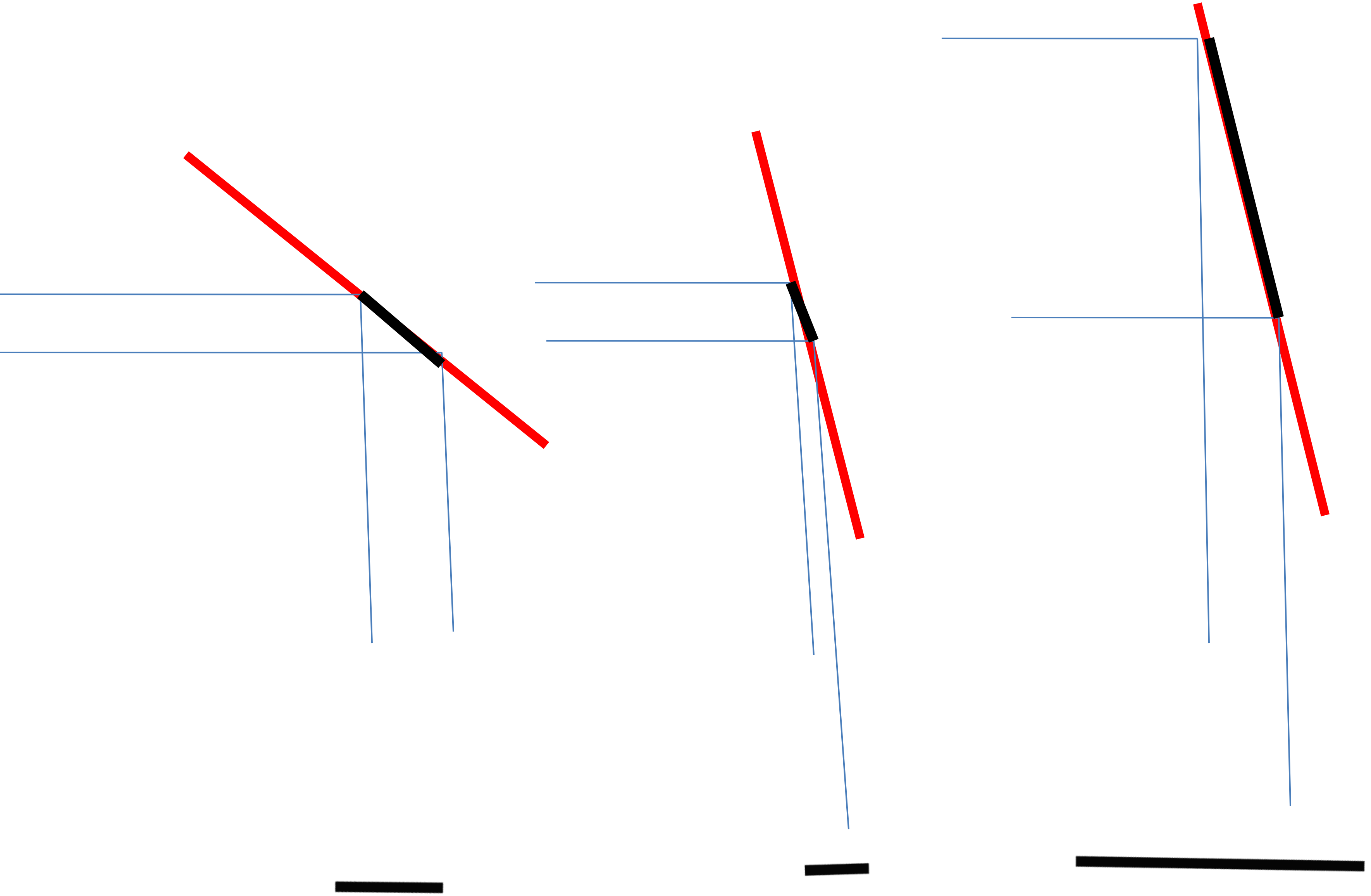


- Tube rating (allowable mA) depends on:

1) ↑ exposure time → ↓ tube heat rating
2) ↑ kV → ↓ tube heat rating
3) ↑ effective focal spot size (by using the larger filament) → ↑ tube rating
4) ↑ target angle → ↓ tube rating
5) Rotating anodes have higher tube rating than stationary anodes
6) High speed anodes have higher tube rating than low speed anodes
7) Constant potential tubes has higher tube rating than pulsating single phase tubes

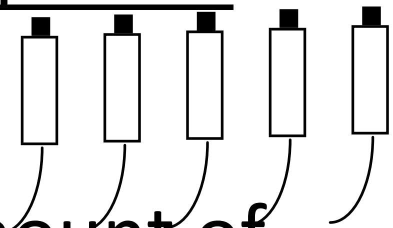
Control system of the equipment prevents exposures exceeding tube rating





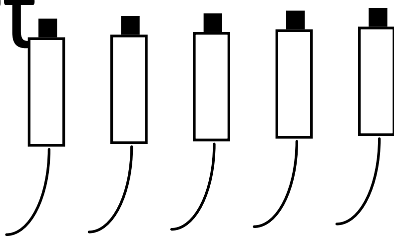
So that decrease target angle increase heat production , BUT ALSO increase tube heat rating

2)Tube rating for repeated radiographic exposure



- Example : angiography
- Tube rating depends on maximum amount of heat that can be temporarily stored in the anode , and the rate by which the anode lose heat by cooling processes

Angiographic Rating Chart



- Provides maximum heat load per exposure for given number of
  - exposures per second
  - total exposures

Total # of Exposures

Exposures per second	2	5	10	20	30
1	37,000	24,000	16,000	10,000	7400
2	25,000	17,000	12,200	8,000	6,200
3	19,000	13,600	10,000	7,000	5,300
4	15,500	11,400	8,600	6,000	4,500

Maximum heat Load allowed in Peak kV X mA X sec.

Control system does not allow operator to choose exposure number or frequency which will exceed heat capacity for the given KV and mA

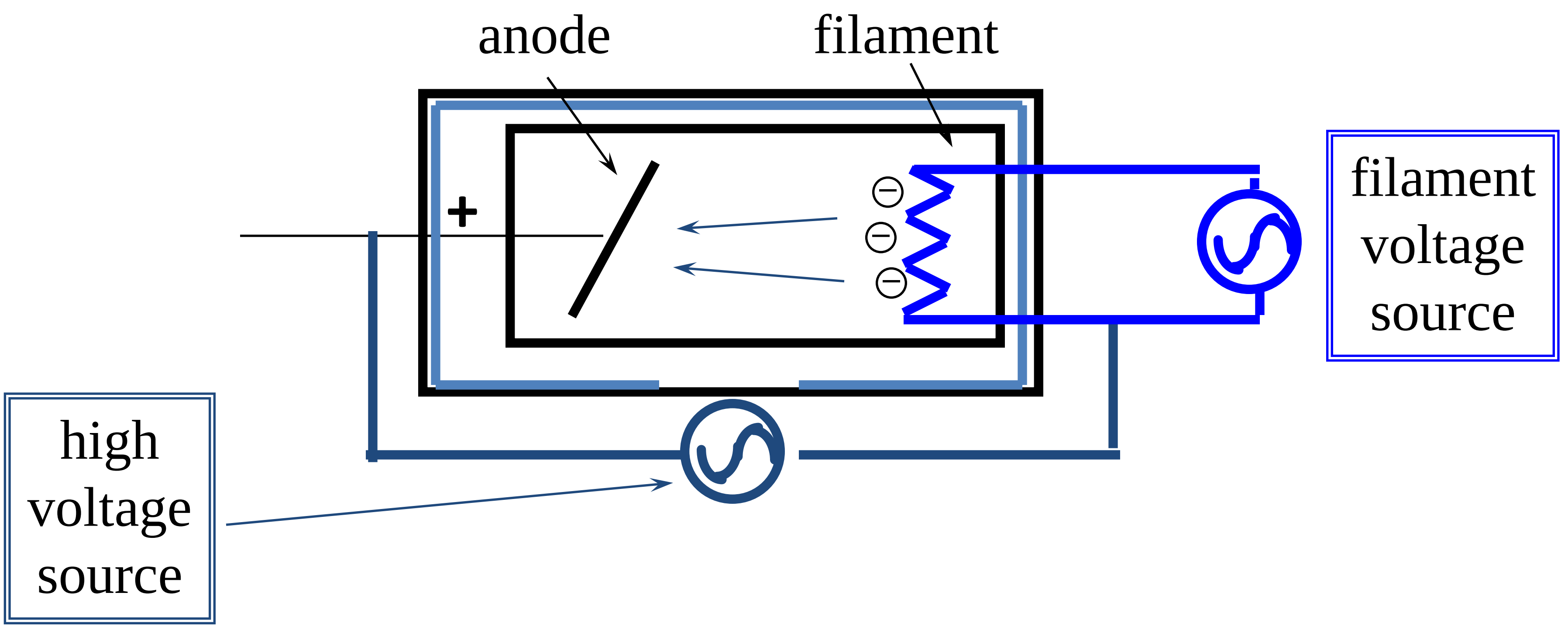
3)Continuous operation (fluoroscopy)

- Heat must be removed at the same rate of its production
- → tube rating is dependant ONLY on rate of heat removal from the tube
- Tube rating is expressed in terms of tube power (J/s = watts)
- e.g. Tube power = 350j/s (watts) → we can use the equipment at 4mA and 90 kv

Other ratings

- Maximum Kv: depends on insulation of the tube and cables (about 150 kv)
- Maximum mA: depends on filament heating capacity (about 700 mA)
- Rating of generators which produce high voltage supply : expressed in KW (why)

e.g. 50 kw generator can operate at 500 mA and 100 Kv

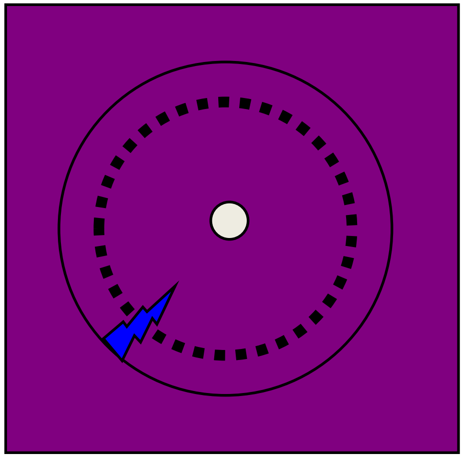


Tube damage

Anode Damage

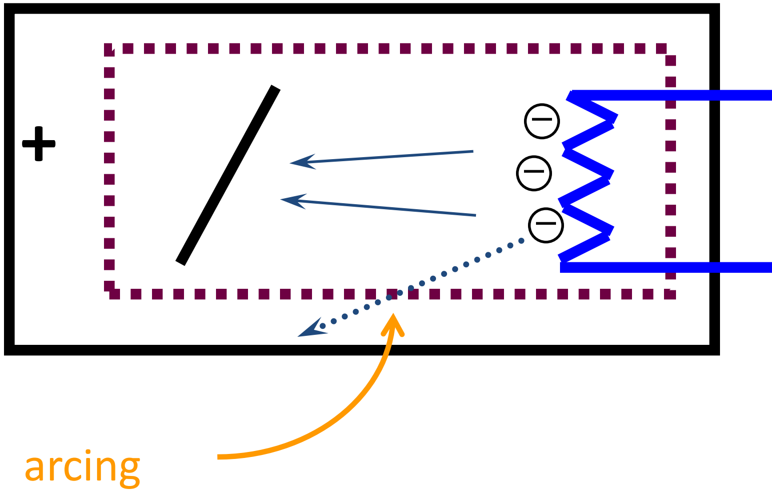
1) Heat capacity exceeded→ melted spots on anode
2) Anode Thermal shock (high mA on cold anode) → cracks in anode

Tube warm-up must be performed to protect the anode



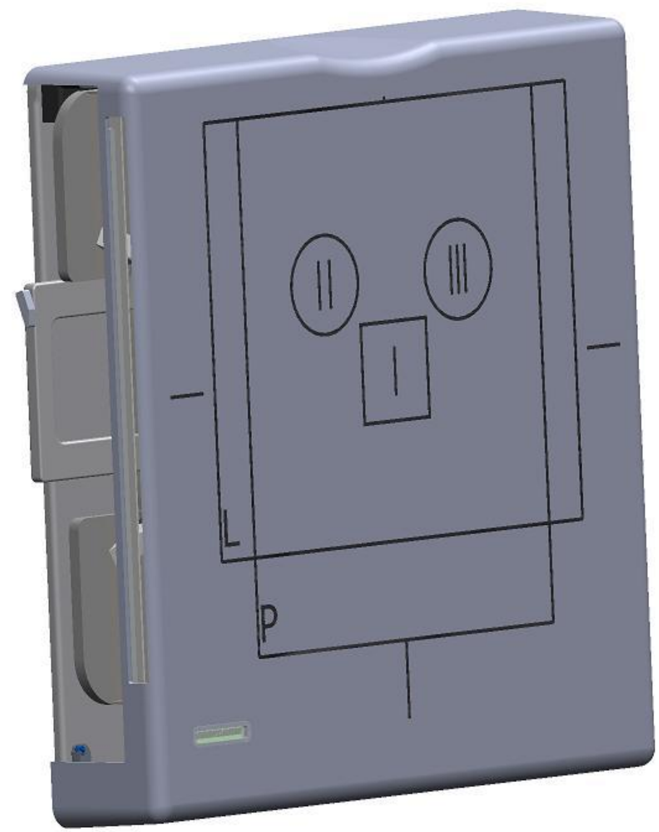
High Voltage Arcs

- very short exposure with instantaneously very high mA
- electrons move from filament to tube housing instead of to anode
- can be caused by filament evaporation



Bucky assembly

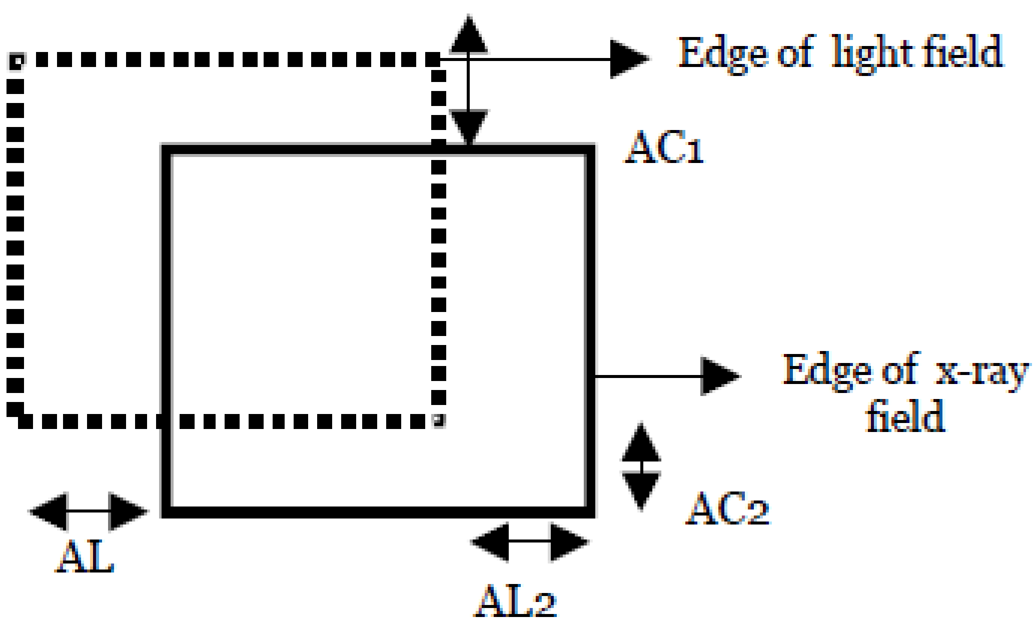
- Positioned behind the patient
- Consists of Cassette holder ,the grid and automatic exposure control system



Some performance tests

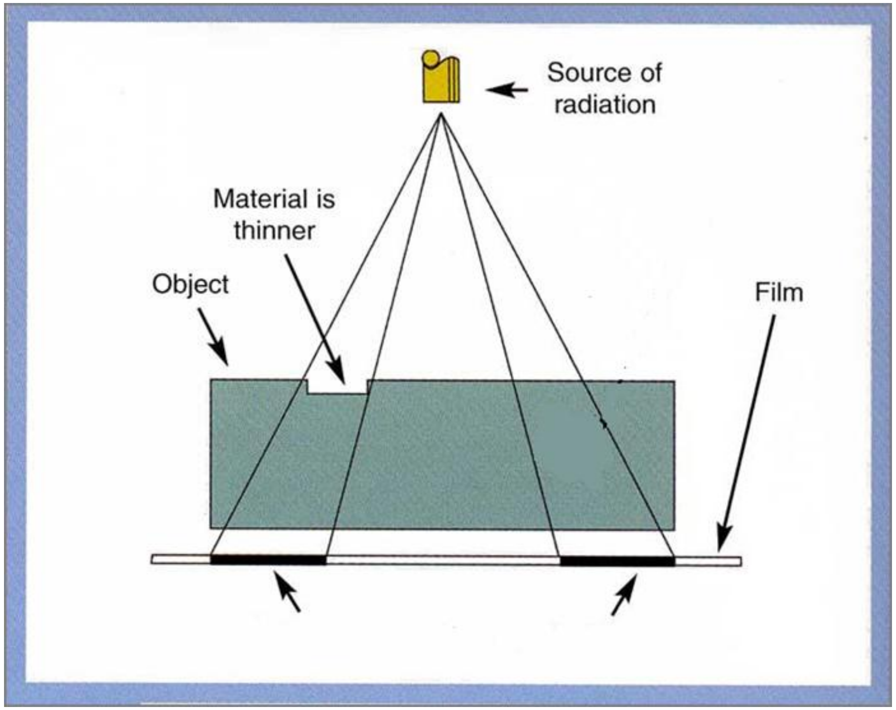
Light beam diaphragm alignment:

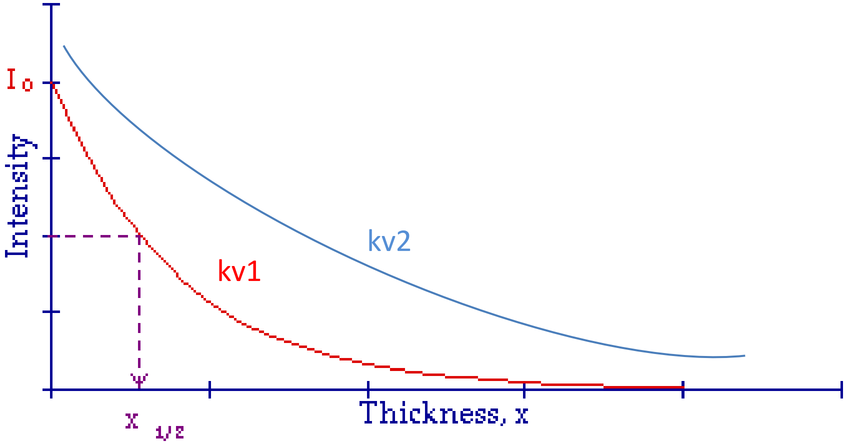
- light beam and x-ray beam matches
- Bucky centering: center of the field lies in the center of the film (when inside bucky assembly)
- Using metal frame adjusted to the light beam
- Discrepancy up to 10 mm is acceptable



Kilovoltage assessment using penetrameter (kv-meter):

- Two filters of the same material and different thickness
- Kv is known according to ratio of response of both detectors
- Accepted errors : 5 kv (1kv for mommo)



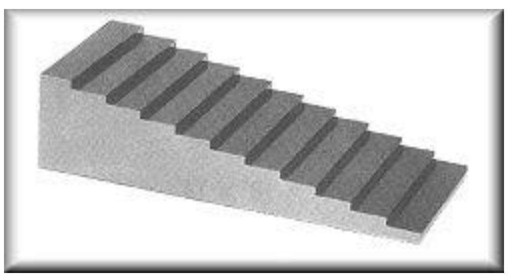


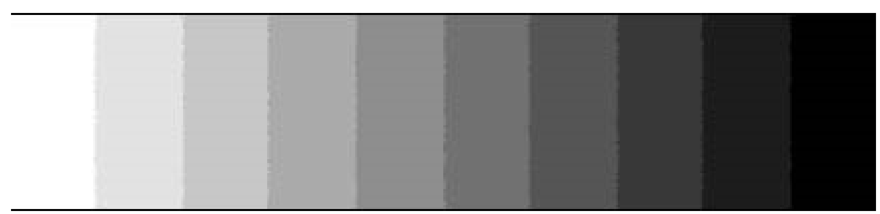
X-ray output using dosimeter:

- Using ionization chamber
- Kv α I^2
- mAs α I
- Any discrepancy → malfunction of kv , mA or ionization chamber

Step wedge:

- Usually of aluminum
- Radiograph is taken to the wedge →optical density of one or more steps are measured using densitometer and compared to the baseline value.
- Constancy test (does not identify the problem), may be due to kv , mA , or film processing



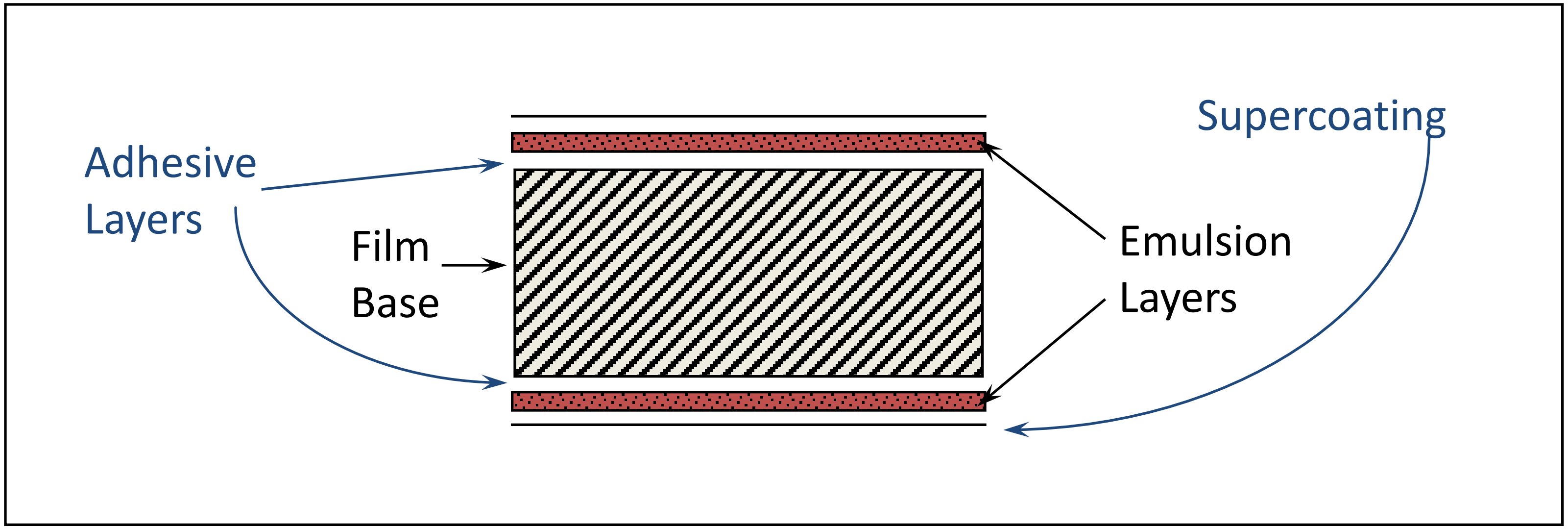


Film screen radiology

Physical Characteristics of X-Ray Film & Film Processing

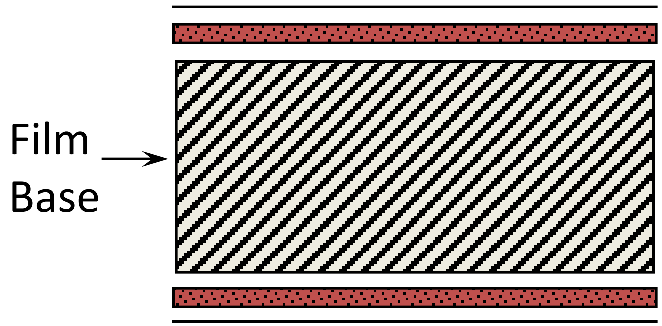
X-Ray Film Construction

- Film polyester base
- Adhesive layer
  - attaches emulsion to base
- Emulsion layer
- Antistatic Supercoat



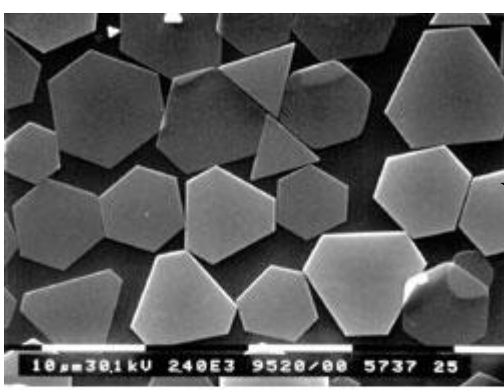
Film Base

- structural support for fragile emulsion
- low light absorption
- no visible pattern
- flexible, thick, & strong
  - For easy handling
- dimensional stability
  - in processing

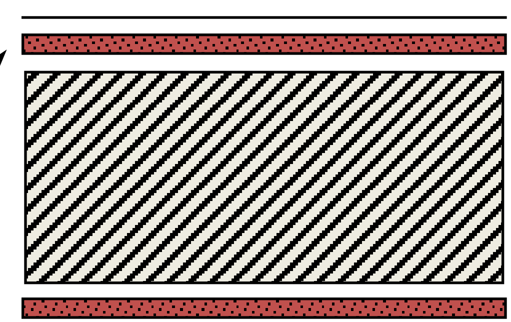


Emulsion

- Most films use two emulsions
- Suspension of silver halide (iodo-bromide) crystals in Gelatin
- Each crystal is 1 µm in size , and contain millions of silver atoms
- Gelatin:
  - keeps silver halide grains dispersed / prevents clumping
  - allows penetration of processing solutions

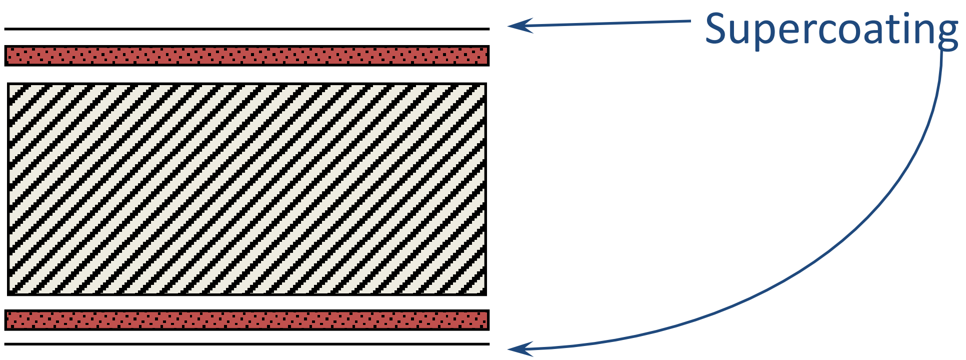


Electron micrograph of tabular grain emulsion



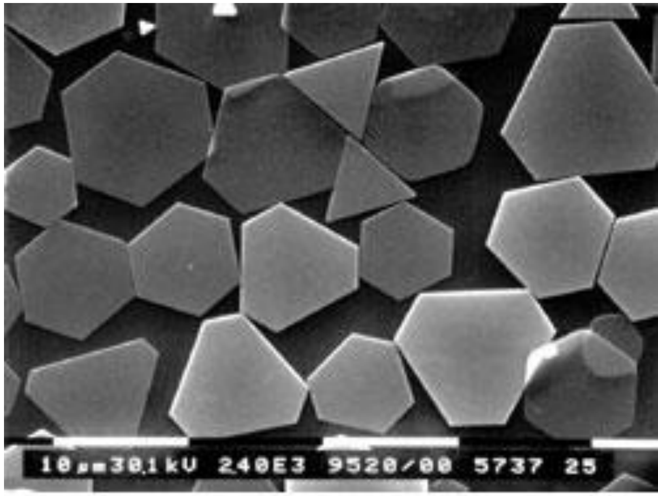
Supercoating

- Thin supercoating covers emulsion
- protects from mechanical damage and abrasion
- Does not curl



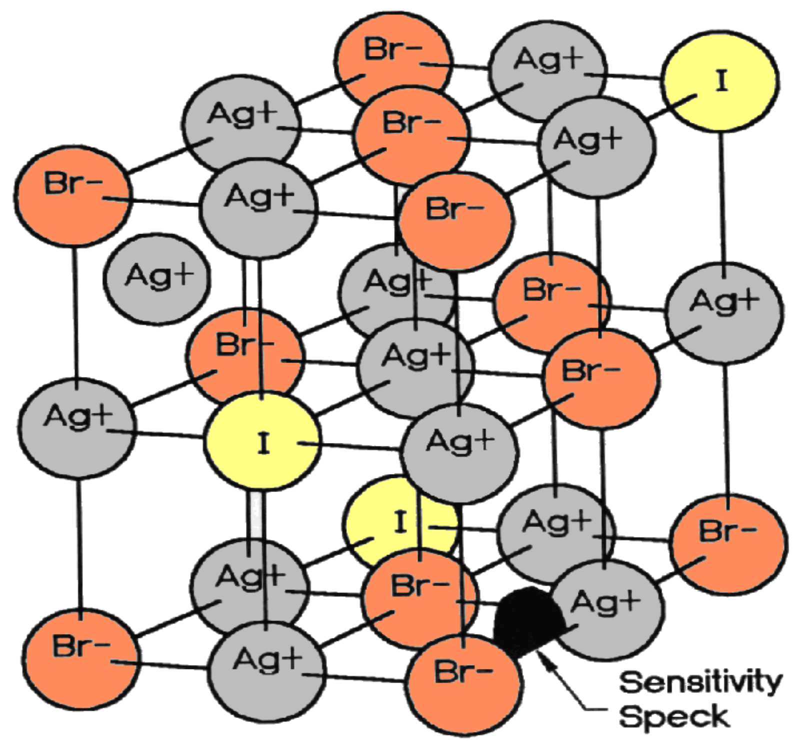
Silver Halide

- Sensitive to light and ultraviolet , but less sensitive to x-ray
- 90 % are silver bromide
- 10% are silver iodide
  - increases sensitivity , distort the lattice so that allow some silver ions to move through the lattice
- Affected by mechanical pressure , creasing , static electricity , chemicals and vapors (careful storage)

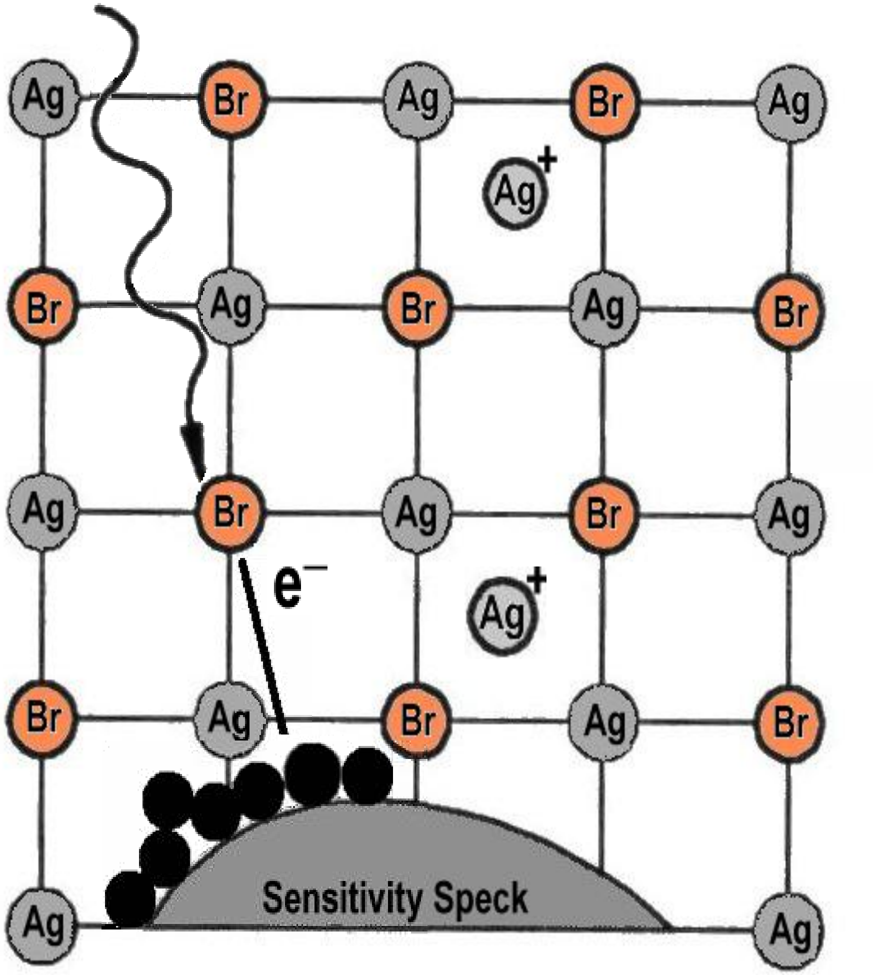


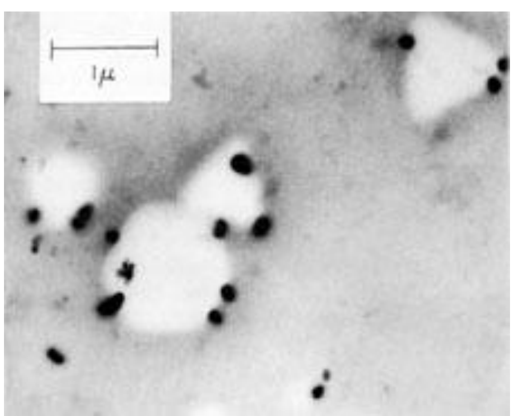
Electron micrograph of tabular grain emulsion

- chemical sensitization of crystal
  - sulfur-containing compound added to emulsion
  - silver sulfide formed
    - usually located on crystal surface
    - called **sensitivity speck**



Latent Image Formation



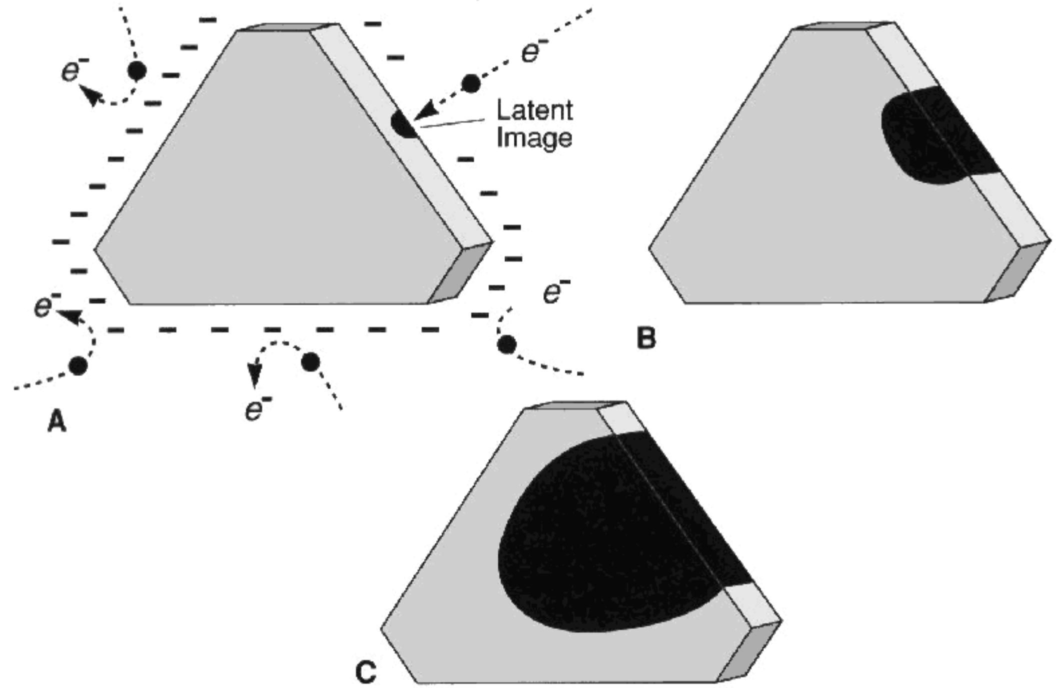


- Light photon absorbed by/ejects Br electron
- Electron trapped at sensitivity speck (lowest potential energy)
- When enough electrons are accumulated →-ve electron attracts mobile Ag^{+} ion
- Ag+ and e^{-} combine to form neutral silver atom
- Distribution of silver atoms within the emulsion forms latent image

Film Processing: Steps

- Development
- Fixing (including stop bath)
- Washing
- Drying

DEVELOPMENT



Developer: alkaline solution of a reducing agent (electron donor) it reaches:

1) **Exposed crystal area (with silver ions at sensitivity specks):** developer reduce positive silver ions to silver atoms by giving them electrons →latent image grows

2) **Unexposed crystal area** : bromine ions repel electrons from developer →no image formed

- Image now is metallic silver

Notes:

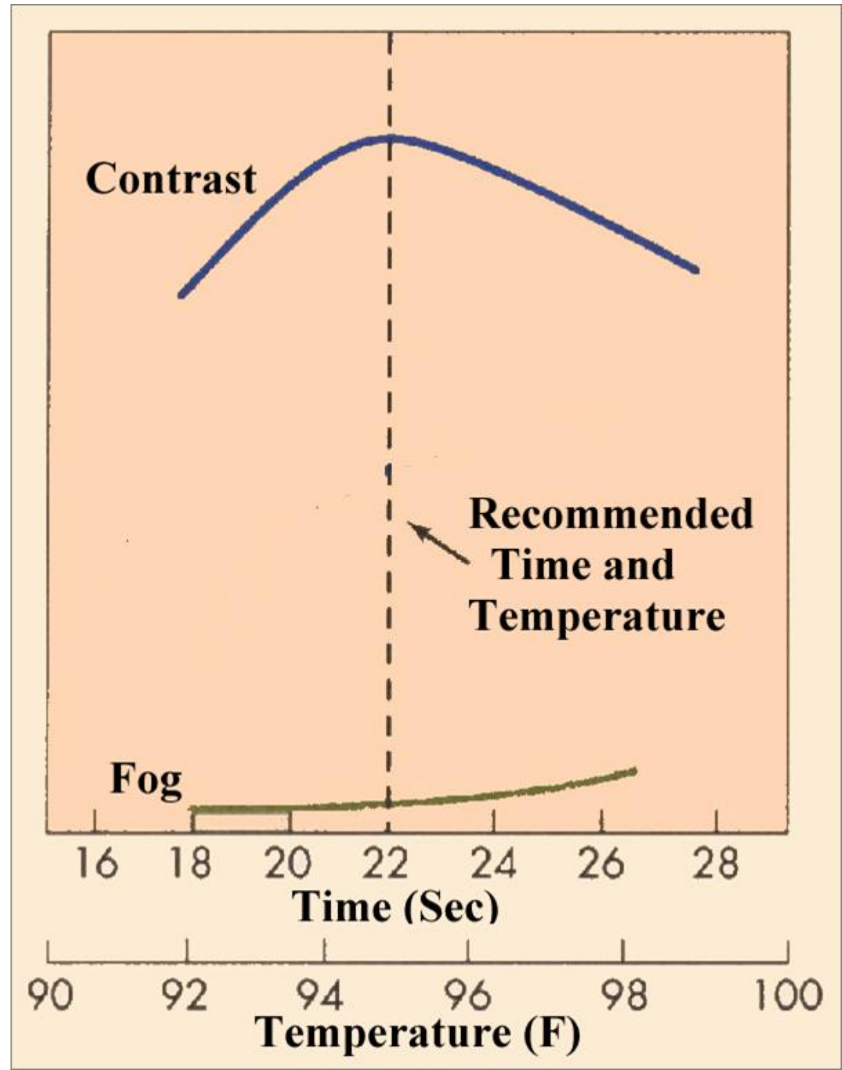
- Background fog: results from penetration of the unexposed crystals by the developer
- Increase with increase of

-1) developing time

-2) developer strength and

temperature

Effect → decrease contrast



Notes:

- Developer solution also include:

-Alkali Buffers: Controls pH

-Restrainer: Inhibits development of unexposed crystals

-Preservative: Reduces oxidation of developer by O_2 in air

Film Fixation

- Acid solution: thiosulfate or “Hypo”

  Removes undeveloped silver ions → image is stable and is unaffected by further light

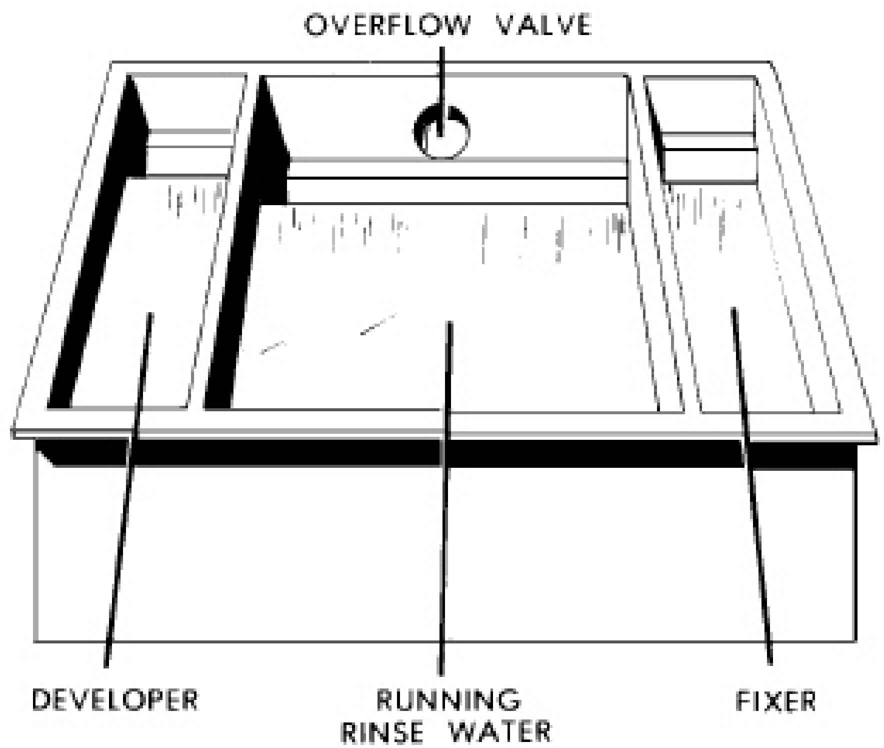
-Fixation solution also includes:

- Activator: Acetic Acid which neutralizes residual developer
- Hardener: e.g. Alum: hardens emulsion for archiving
- Preservative:
  – Similar type and functions as for developer

- Film washing in water : remove retained hypo

Inadequate washing → brown yellow film with vinegary smell

- Film drying by hot air

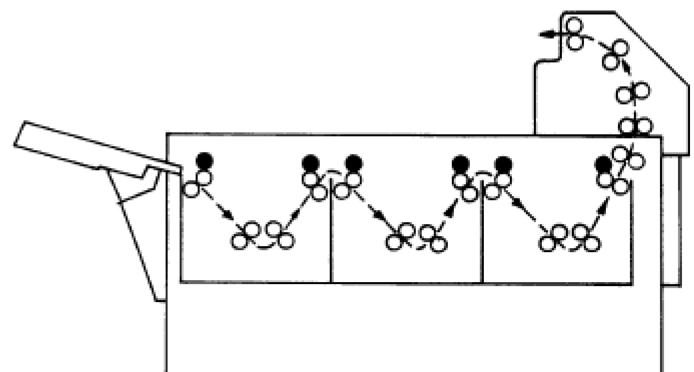


Automatic Film Processing

Roller feed system transport the film automatically through different solutions

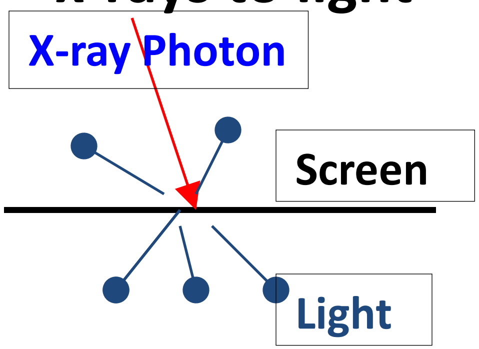
Advantages of Automatic Film Processing

- Less processing time is required.
- Time and temperature are automatically controlled.
- Less equipment is used.
- Less space is required.



X-Ray Intensifying Screens

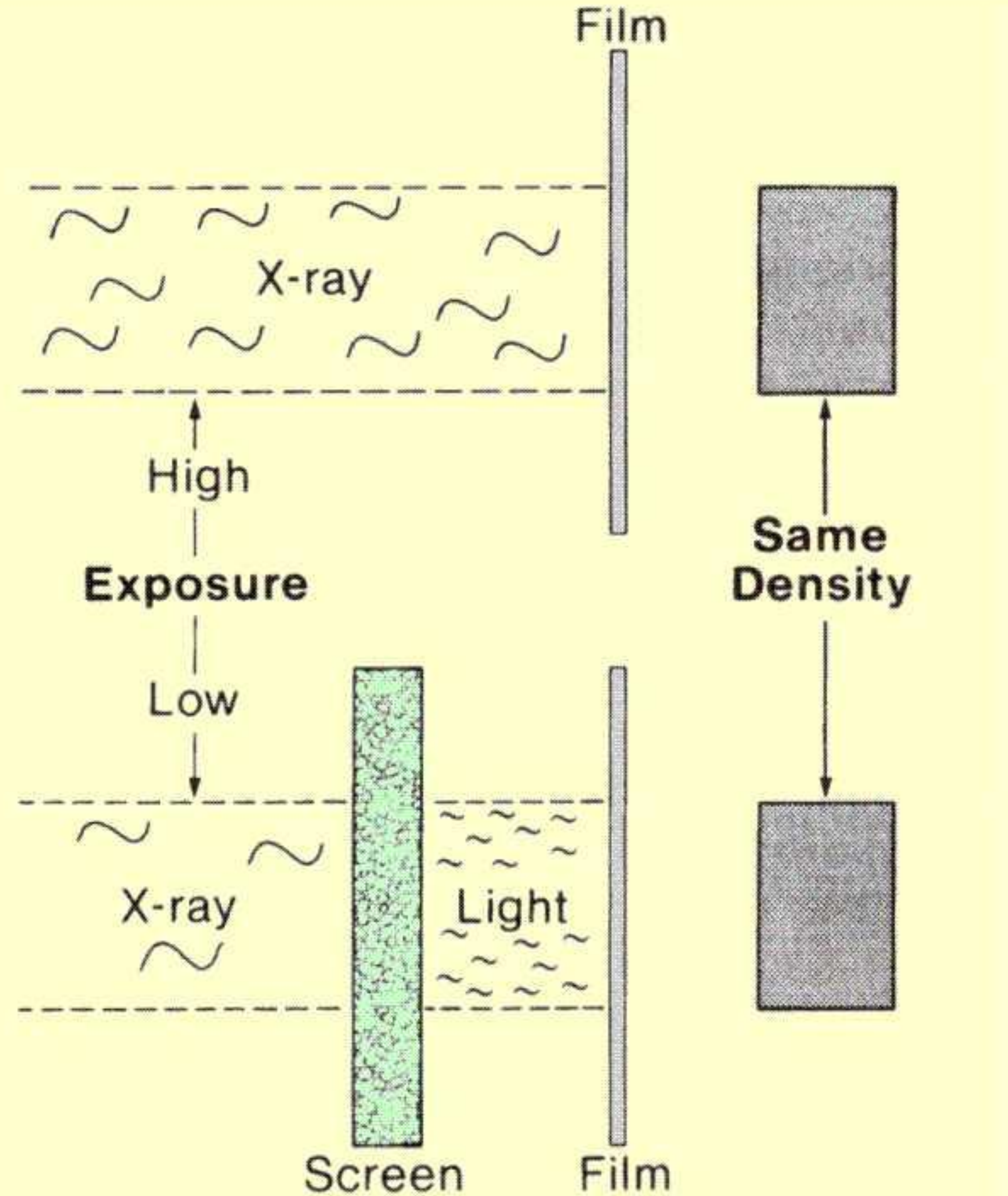
- X-ray film is relatively insensitive to x-ray → require high dose to produce acceptable image
- The screen is a phosphor →Convert **x-rays to light**



•Light from screen exposes film

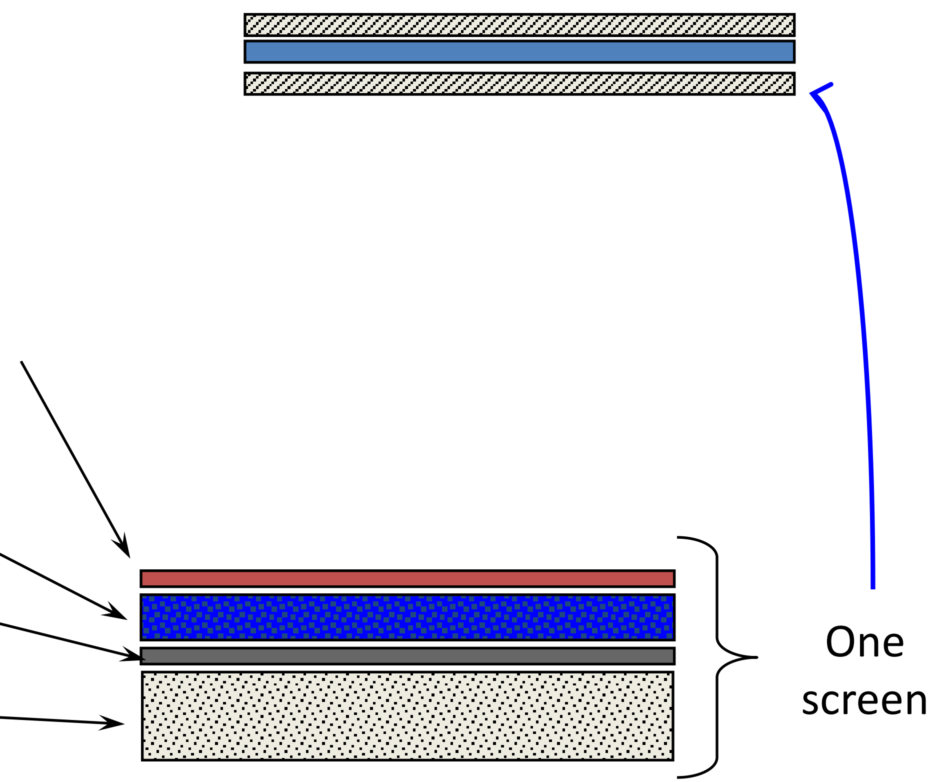
•Intensity of light emitted from screen is α intensity of x-ray fallen on the screen

•Screens reduce patient dose (film much more sensitive to light)



Screen Construction

Screen is the same size as the film

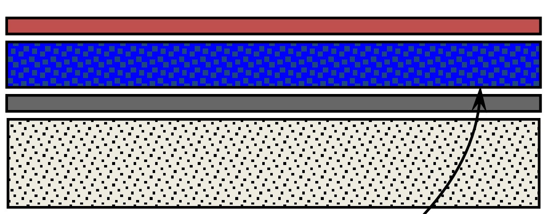


Formed of:

- plastic protective coat
- phosphor layer
- reflecting layer
- Polyester base layer

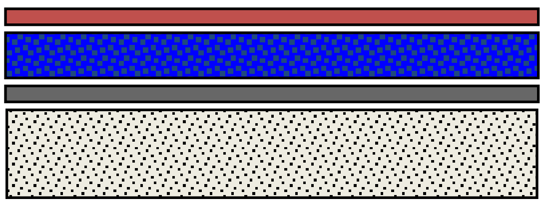
Screen Construction

- Protective Layer
  - applied over phosphor
  - made of plastic
  - Functions
    - prevents static electricity
    - provides physical protection

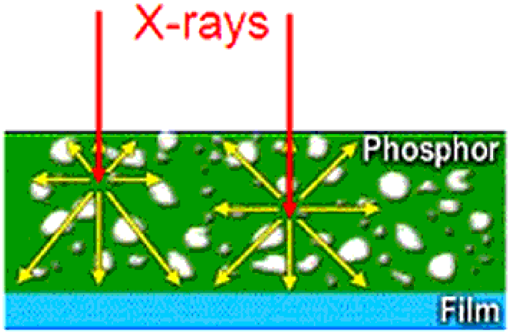


- Phosphor Layer
  - contains phosphor crystals (3-10 µm each)
  - Layer is 0.1-0.5 mm thickness

Screen Construction



- Reflecting Coat
  - reflects light emitted toward back of screen
    - phosphors emit light in all directions



- Polyester Base Layer
  - Mechanical support
    - 0.25 mm thick

Phosphor materials used in the screen

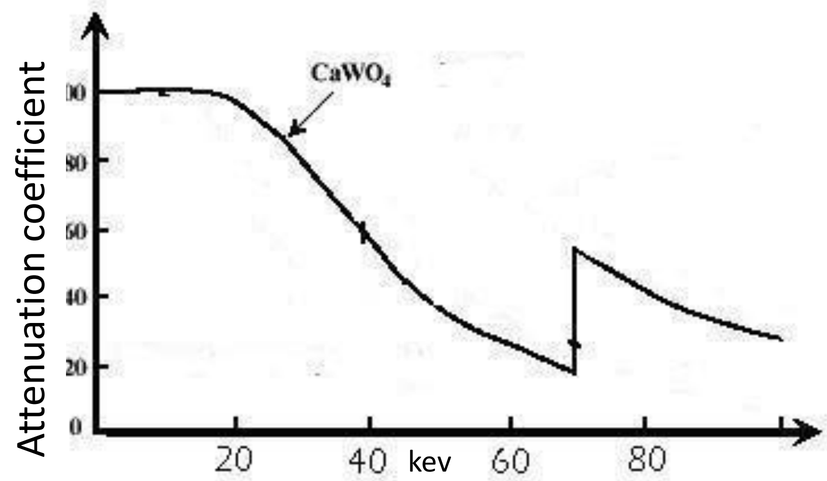
Each phosphor emit certain spectrum of light

The sensitivity of the film used must match the emitted light spectrum

1)calcium tungstate :

- Traditional phosphor
- Emit blue light
- Attenuation coefficient is affected mainly by tungsten (Z=74)

Disadvantages:
1)Relative low attenuation at diagnostic x-ray spectrum
2) Poor attenuation of characteristic radiation (why?)



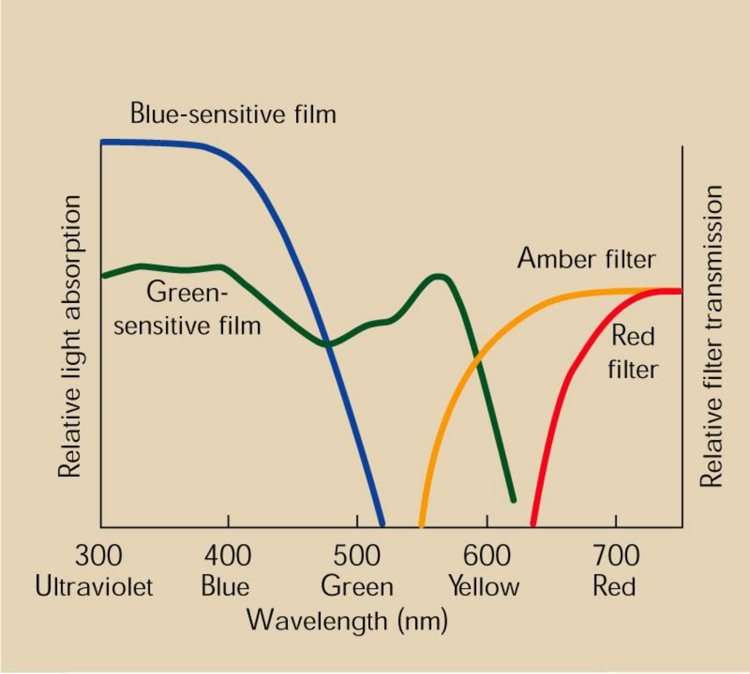
- 2) Rare earth materials:
- All of them contain impurities = activators (why?)
- Phosphor type will determine the intensity of emitted light (why?)
- Phosphor and Activator type will determine the color of emitted light (why?)
- Lanthanum oxibromide activated with terbium: blue light→ can be used with ordinary x-ray film
- Lanthanum oxisulphide or Gadolinium oxisulphide activated with terbium : green light → used only with orthochromatic film

Notes:

- Rare earth materials Z = 57 – 70
- Rare earth materials K- edge = 39-61 kev (suitable for x-ray spectrum)
- The safe light used in the dark room depends on the film sensitivity:

For ordinary x-ray film →use amber safe light

For orthochromatic film → use red safe light

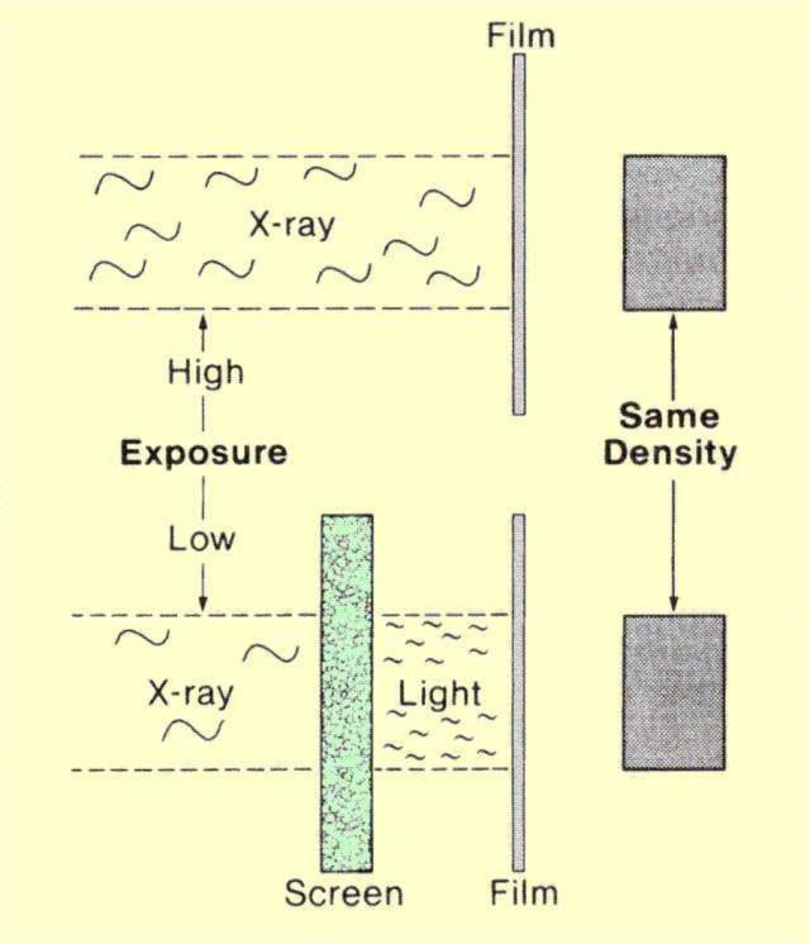


- Screen materials are characterized by fluorescence not phosphorescence (to avoid retaining memory of previous exposures)

Intensification Factor

$$= \frac{\text{Air kerma required without screen to produce D=1}}{\text{Air kerma required with screen to produce D=1}}$$

= 30-100



N.B: Increase KV (over the range of kilovoltages used in Radiology) → increase intensification factor.

Comparison between x-ray and light photons interaction with the film

	Without sceen	With screen
Percentage of incident X-ray photons which is absorbed (detection efficiency)	2%	30%
Number of photons required to produce single latent image	1	100

Intensification process = conversion efficiency :
each X-Ray photon produces 600-1000 light photon in the screen

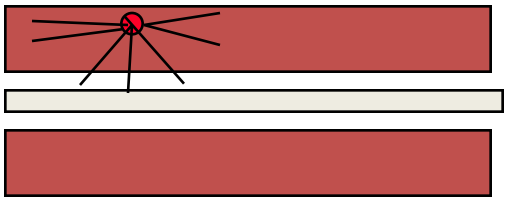
In case of screens: Although less effective in latent image formation , combination of:

1) high detection efficiency = absorption efficiency
2) High conversion efficiency = intrinsic screen efficiency
3) Use of reflective layer

Will result in decreased patient dose and increase of intensification factor

Screen Efficiency

- Fraction of light emitted by phosphor to expose film
- typically <u>half</u> of light emitted by screen reach the film for all phosphor types
- Theoretically increase IF

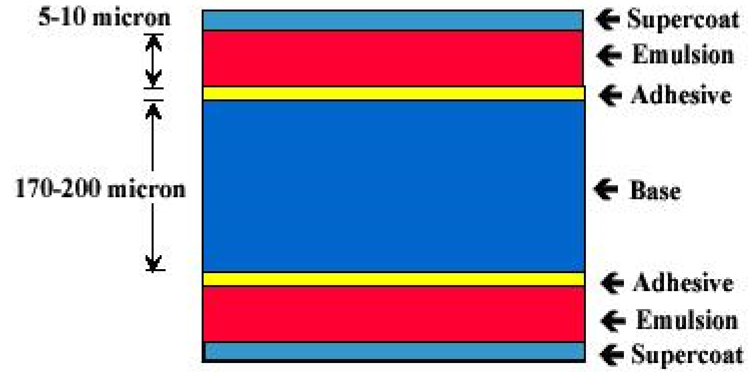


Conclusion

- ***Use of screens reduces:***
  - Patient dose
  - Load on tube and generator
  - Exposure time (and subsequently movement blurring)
  - Allow using of a smaller focal spot)

Double coated film

- Contains emulsion on each side of the base
- Used with pair of screens
- Light from front screen expose front emulsion , and light from rear screen expose rear emulsion
- Effect: increase x-ray absorption:

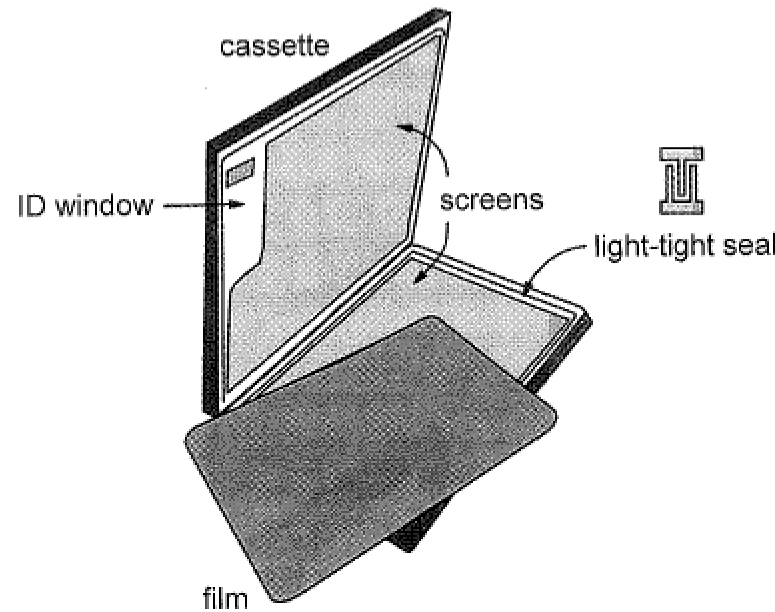


➢ About third of x-ray falling on the front screen is absorbed

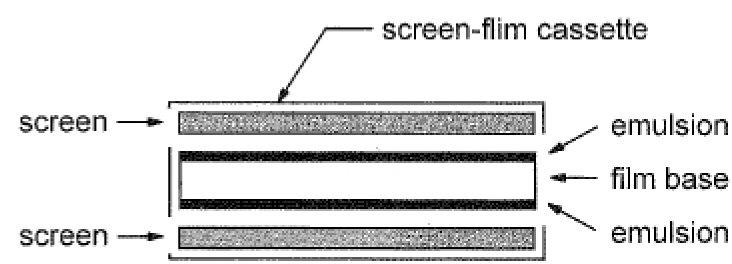
➢ The rear screen absorbs about half of x-ray transmitted by the front screen

➢ →……… of the total x-ray is absorbed

A



B



Advantages of double screen system :

- 1) more absorption of the x-ray
- 2) Two screens produce more light

So that Less radiation is required to achieve the same optical density → less patient's dose

Single coated films are only used in:

- – Nuclear medicine
- – Digital imaging
- – Cineradiography
- – Spot filming with image intensifier.
- – Copying radiographs

Direct-Exposure Film

- Thicker emulsion and more crystals
- Not commonly used because of increased patient dose (used in intraoral dental radiography)

- Very detailed images

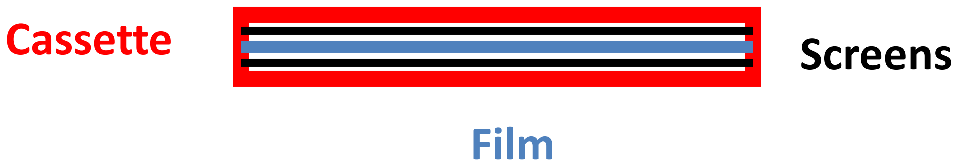
X-ray Cassettes

X-ray Cassettes

Cassettes serve 3 functions:

1. Protect film from exposure to light (light tight)
2. Protect film from bending and scratching during use.
3. Contain intensifying screens, keeps film in close contact to screen during exposure by internal pressure pads. (gaps increase image unsharpness)

Radiographic Cassette

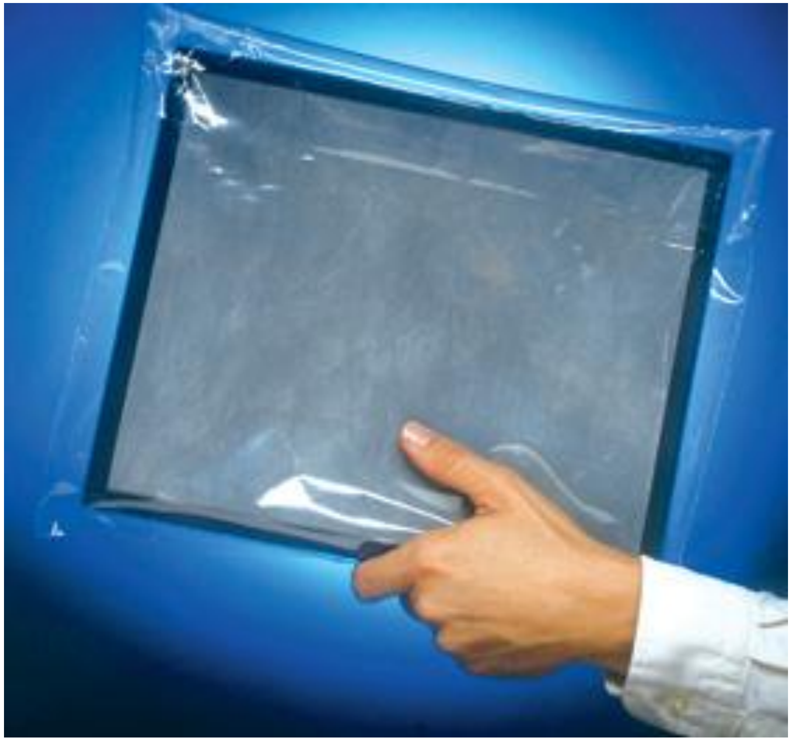


- Contains front and back intensifying screens , and the film in-between

N.B: Dust on the screen prevent screen light from reaching film, causes white dots on image

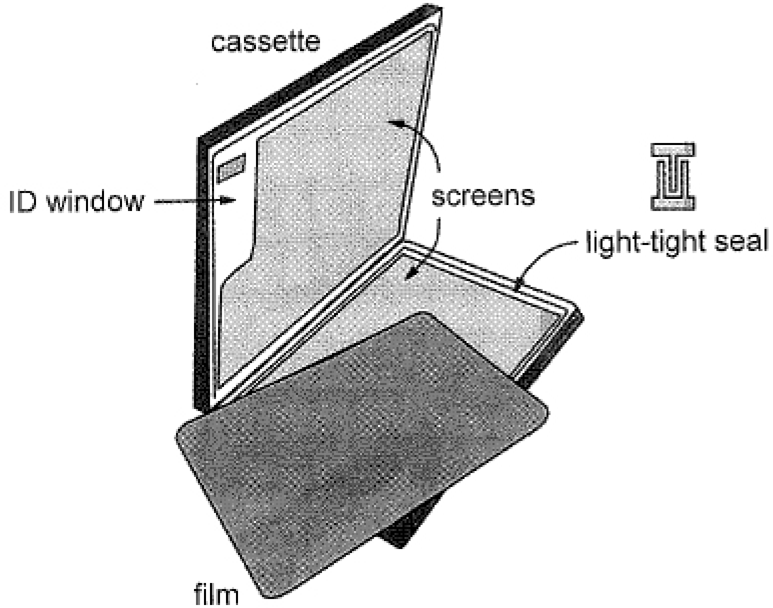
Cassette Features - Front

- Exposure side of the cassette
- Usually made of carbon fiber (↓Z=6 to minimize beam attenuation → decrease patient’s dose)



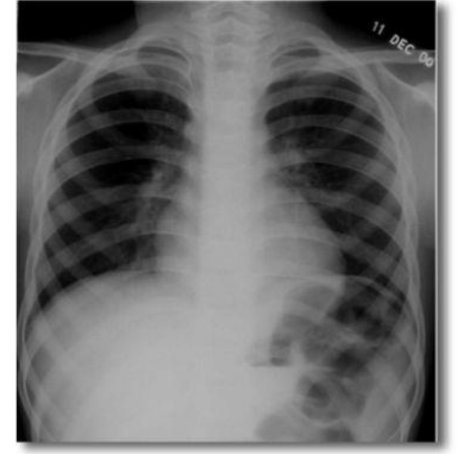
Cassette Back

- Back made of metal
- Inside back is lead sheet – prevents backscatter that could fog the film



Film optical density and Characteristic curve

optical density



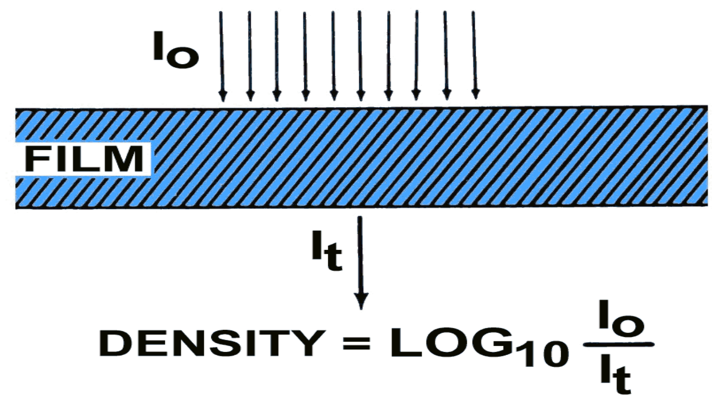
- When image is viewed on the light box

→ it is a negative image of the patient

(sites of silver grains will absorb the light)

- Optical density (D) of area of the film = degree of blackening of area of a film is depended on number of silver grains per unit area
- D = $\log_{10}$ (incident light / transmitted light)

If 1% transmitted → D=……..



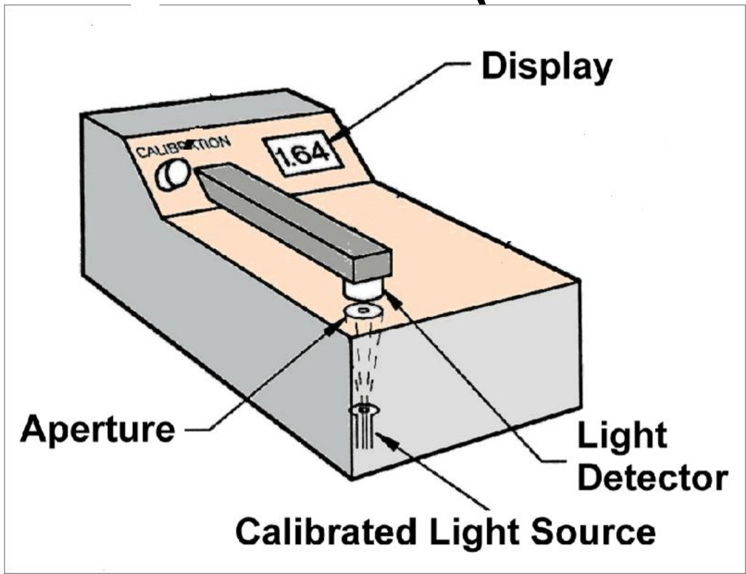
Notes:

1) densities of front and rear emulsion are additive

2) density above 3 is so dark to be revealed by standard light-box and requires bright lamp

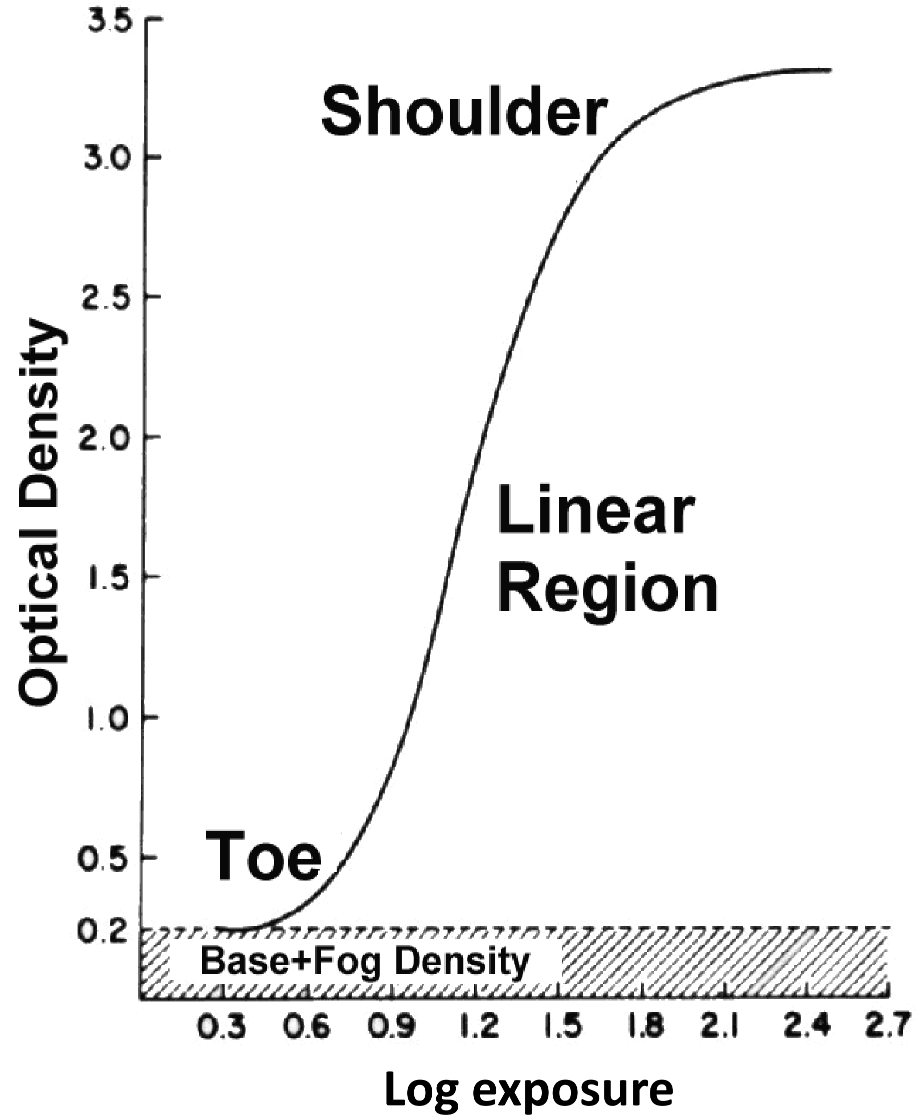
3) eye also responds logarithmically to the light brightness

4) optical density is measured by densitometer (small light source + light detector)



Characteristic curve

- Curve that describes the response of film-screen to the X-ray
- Characteristic to each film
- Optical density is plotted against the log of exposure or air kerma (logarithmic scale)



The shoulder

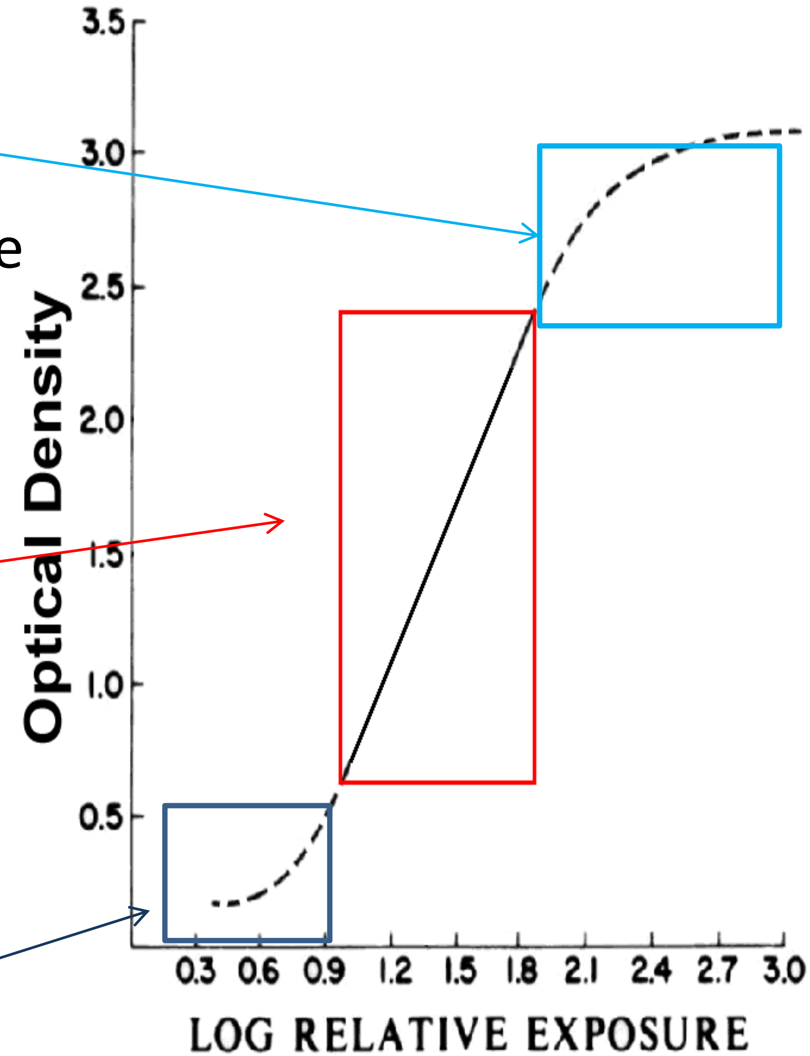
- High densities region , the slope of the curve is shallow (change in exposure results in little density change)

Linear Region

- = region of correct exposure
- Slope is steepest
- The densities of the area of interest must be in that area

The toe

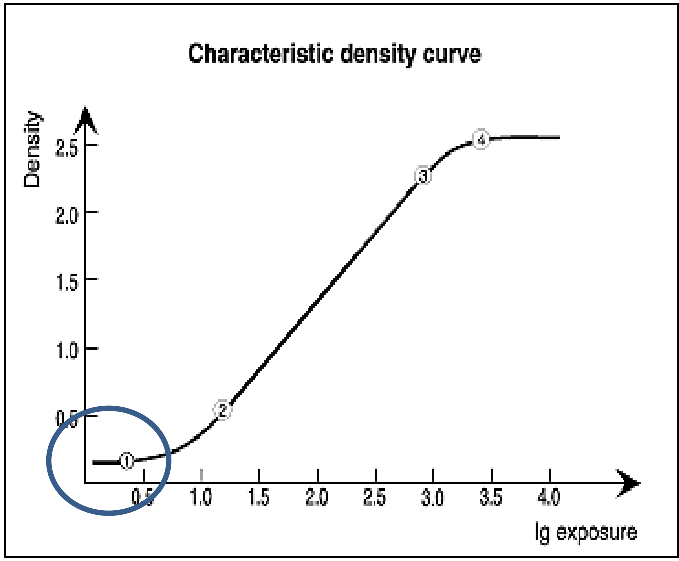
- Low density region in which the slope of the curve is shallow



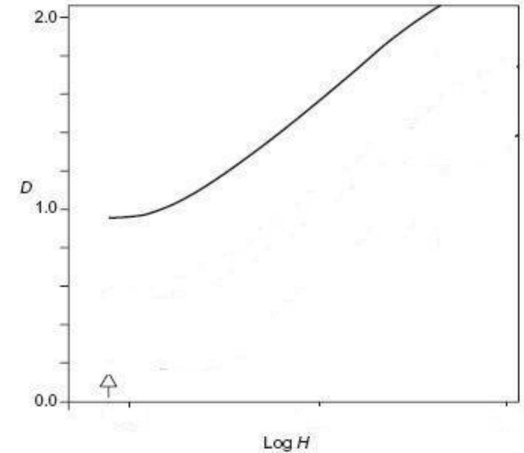
N.B: -Saturation: at higher densities than the shoulder (3-3.5) → the curve flattens (all silver bromide is converted to silver)
-Solarization: at extremely high exposure levels → curve begin to fall (not important to radiographic image)

Base + Fog

- Unexposed film has optical density >0
  - **Base :**
    - 1-Film base absorbs small amount of light when viewed (has blue dye)
    - 2-some silver crystals acquired latent image during manufacture
  - **Fog :**
    - Bad storage (e.g. high temperature)
    - development of unexposed grains (increase with developer strength , temperature and time)



Density of base + fog = 0.15-0.2
Fog decrease film contrast



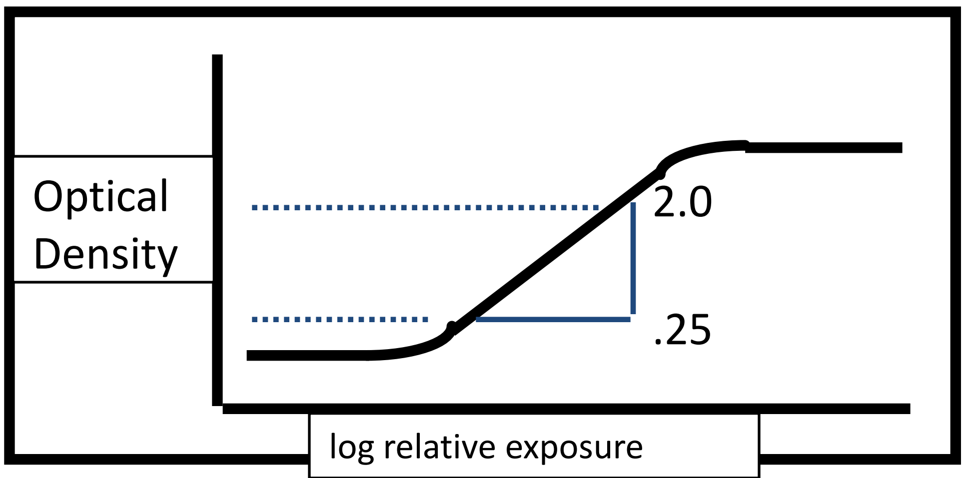
Film Contrast

- Film **Gamma** γ=

maximum slope characteristic curve = slope of linear area

$$\text{Gamma} = \frac{D_2 - D_1}{\log E_2 - \log E_1}$$

- Usually refers to the average slope between net densities of 0.25-2



Note from the equation that:

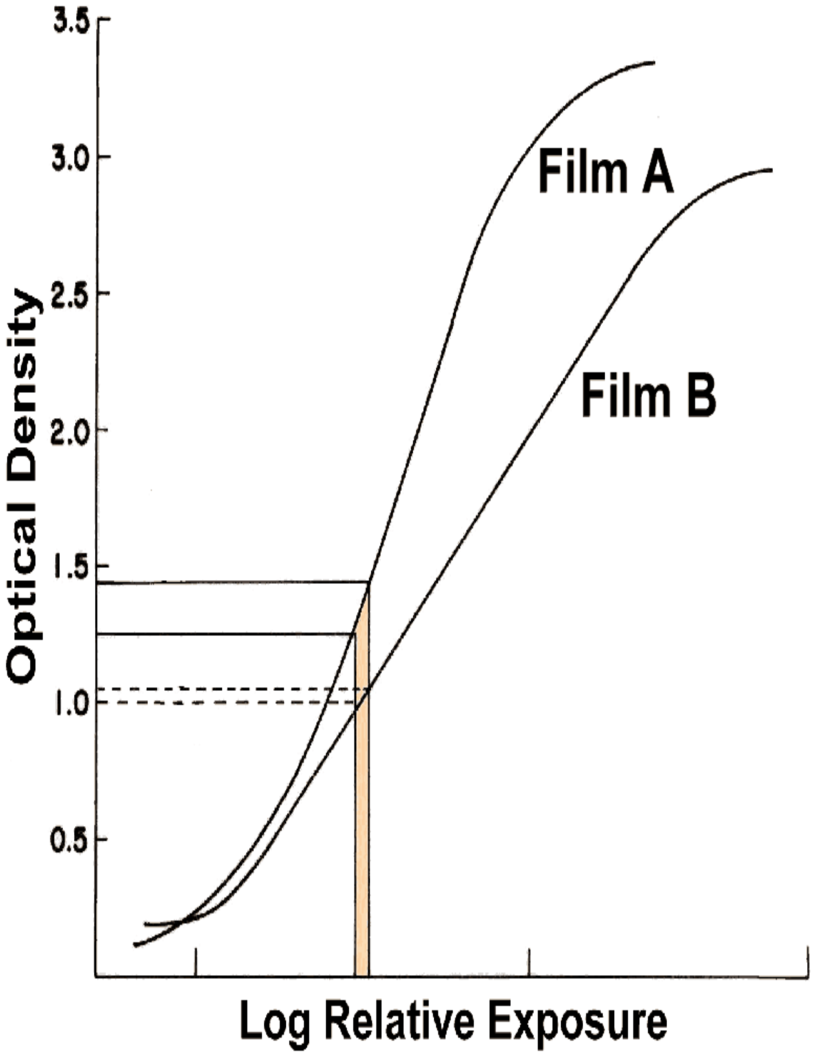
1)

$$\text{Gamma} = \frac{D_2 - D_1}{\log E_2 - \log E_1} = \frac{\text{radiographic contrast}}{\text{subject contrast}}$$

So that If film gamma is >1 → the film will exaggerate subject contrast (typical for x-ray film)

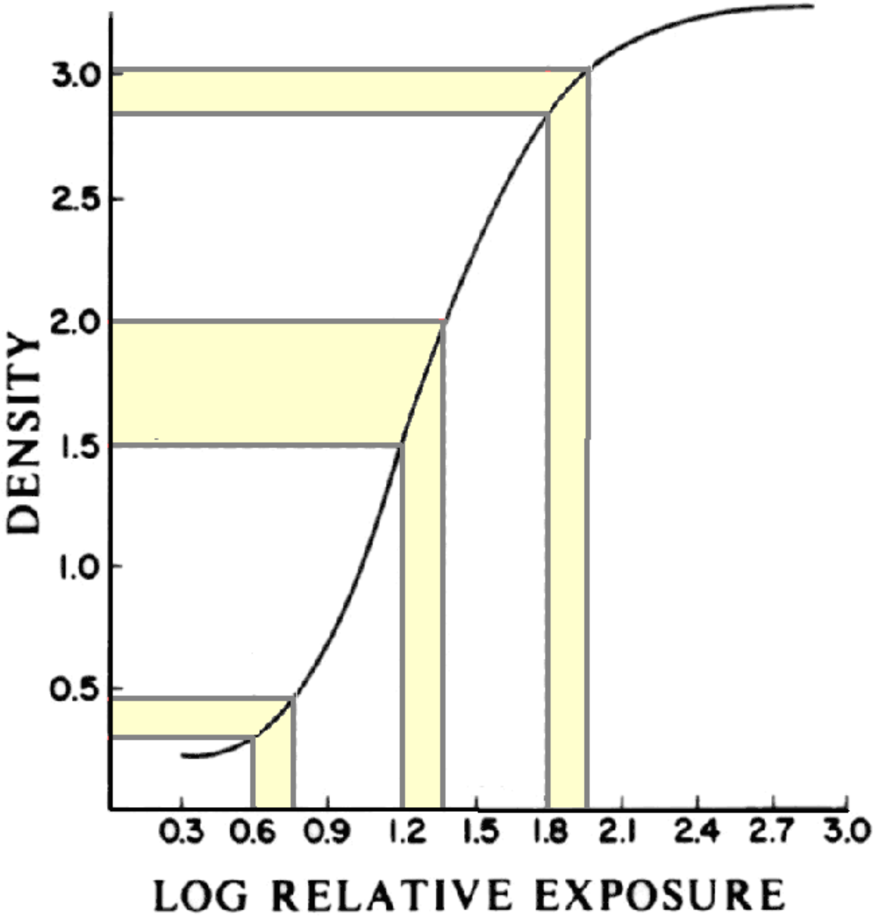
2) Radiographic contrast = subject contrast X film gamma (remember factors affecting the contrast)

Notes:
-Average gamma of X-ray films is 2-3
-Film gamma depends on the range of crystals size (the wider the ranges of sizes , the shallower the curve)

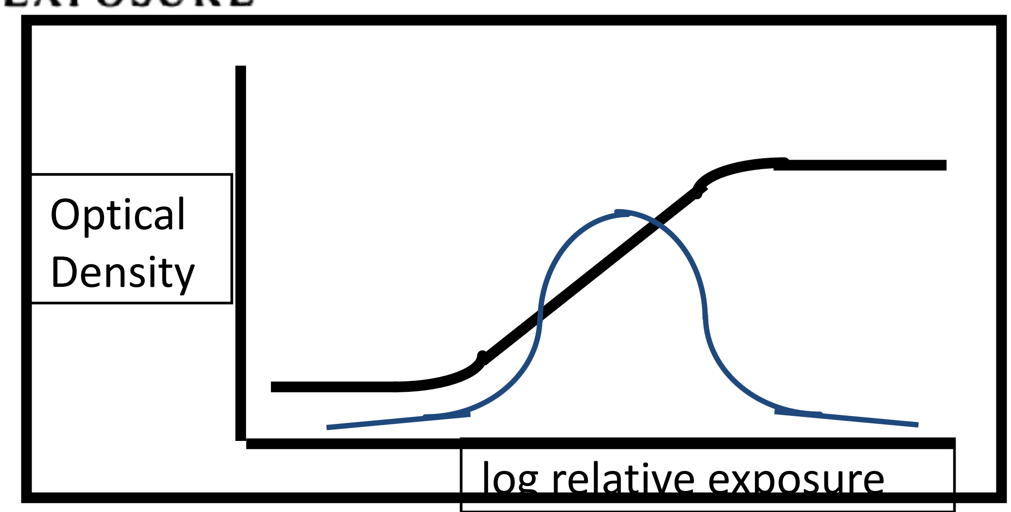


Film A has ………. Contrast than film B

The steeper is the curve (the higher γ) , the ……… the contrast



Note that the contrast of the film is highest at the region of correct exposure (at the linear region)

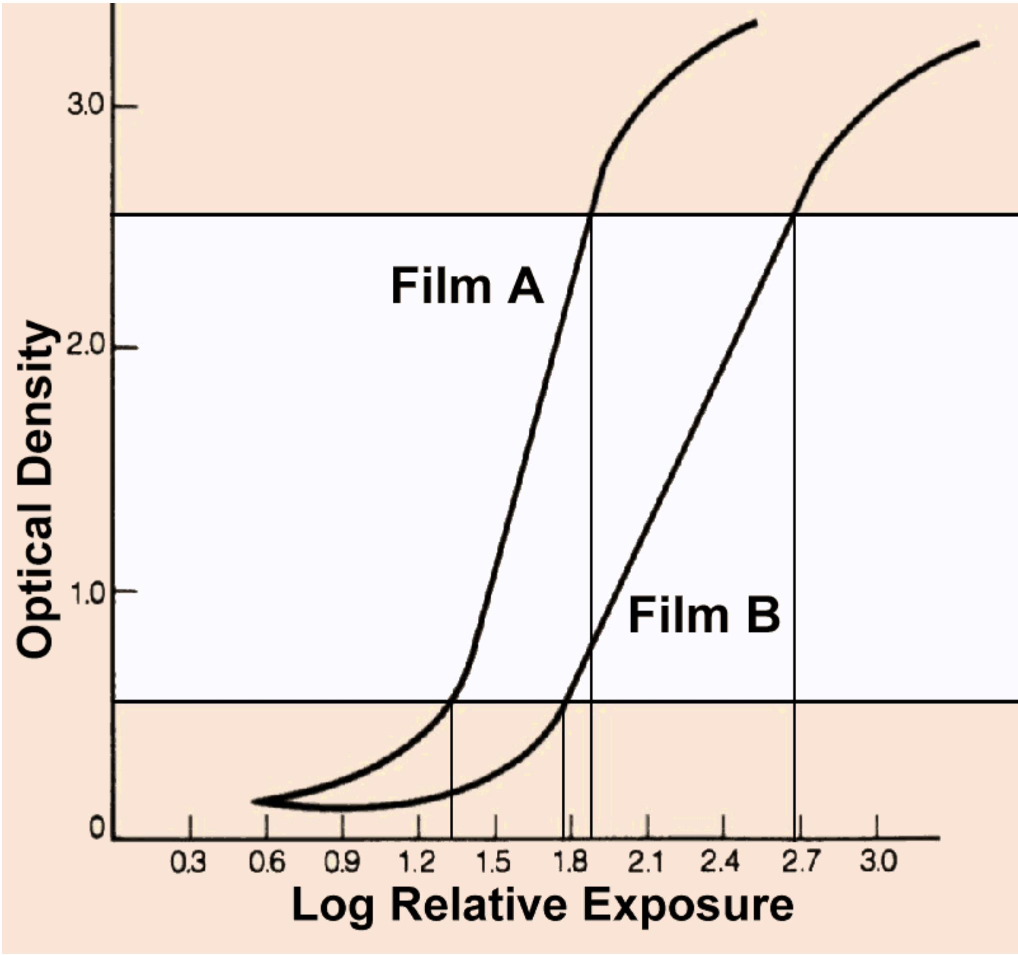


Characteristic Curve

Slope of curve

Film latitude

- Ranges of exposures that produce net densities in the useful density range (0.25-2 above base)
- i.e. Densities beyond which film generally too light or too dark with less contrast
- Expressed in ratio e.g. 5:1



Relation between film gamma and latitude

$$\text{gamma} = \frac{D_2 - D_1}{\log E_2 - \log E_1} = \frac{2.0 - .25}{\log E_2 - \log E_1} = \frac{1.75}{\log E_2 - \log E_1}$$

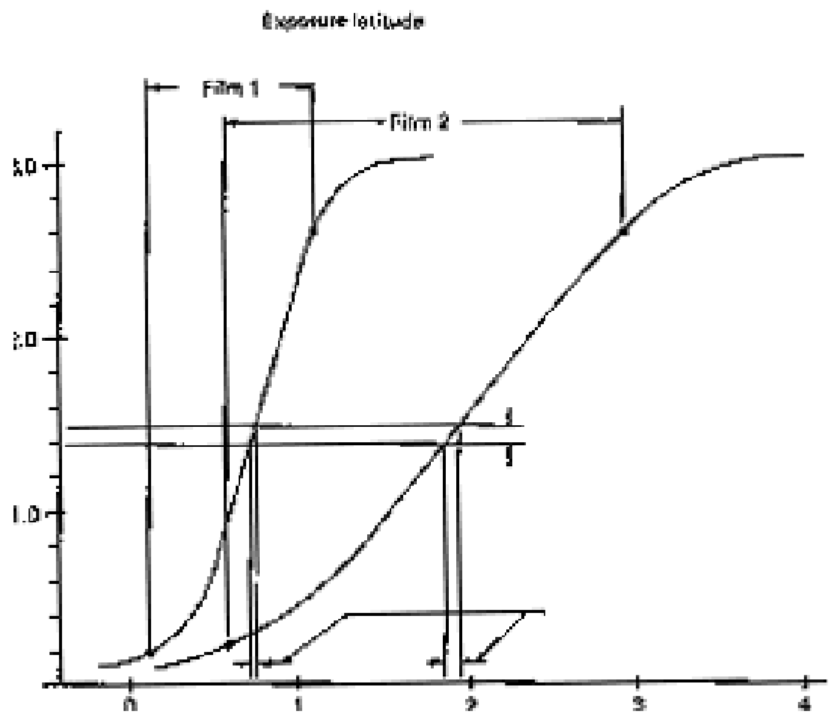
→gamma is inversely proportional to latitude

Examples :

•chest x-ray needs film with wide latitude (wide range of radiations intensities falling on the film)

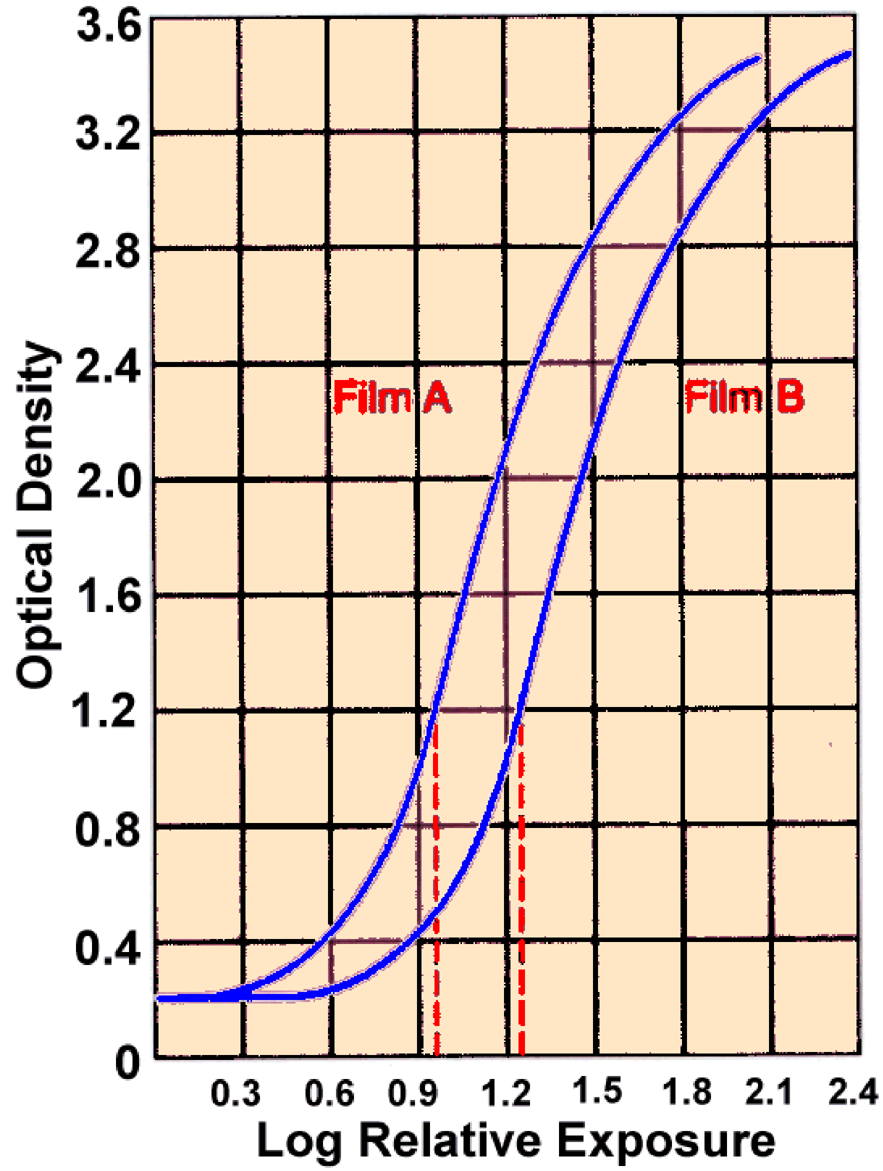
→we sacrifice the contrast

•Mammography needs film with high gamma (low subject contrast) , and does not need high latitude (why?)



Film Speed

- =1000/k
  K= air kerma (in μGy) required to achieve OD = 1.0 above B+F
- Film A is faster than film B
- Speed class is given to specific X-ray beam quality
- E.g. speed class = 400 → 2.5 μGy is required to give density = 1



Film screen speed class depends on

Film speed

1) film type : speed increase with the average size of crystals (smaller crystals → higher exposure needed to form the latent image)

2) Developing process: increase developer temperature, strength and time → increase film speed

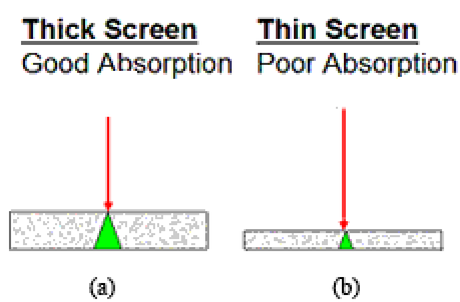
screen speed

3)phosphor type : speed increase with increased

-detection efficiency (absorption efficiency)

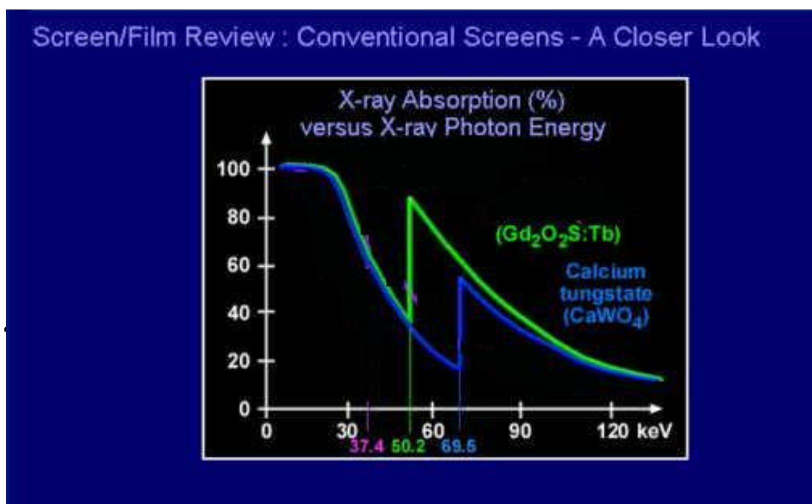
-conversion efficiency (intrinsic screen efficiency)

4) α thickness of the phosphor



5)kv: with use of rare earth speed:

greatest speed is at about 80 kV (why



Application:

- Rare earth material screens are faster than calcium tungstate :

1)More detection efficiency (30% for calcium tungstate and 60% for Rare earth material screens)

2)More conversion efficiency (5% for calcium tungstate and 20% for Rare earth material screens)

- 2-3 Lower dose with the same image quality

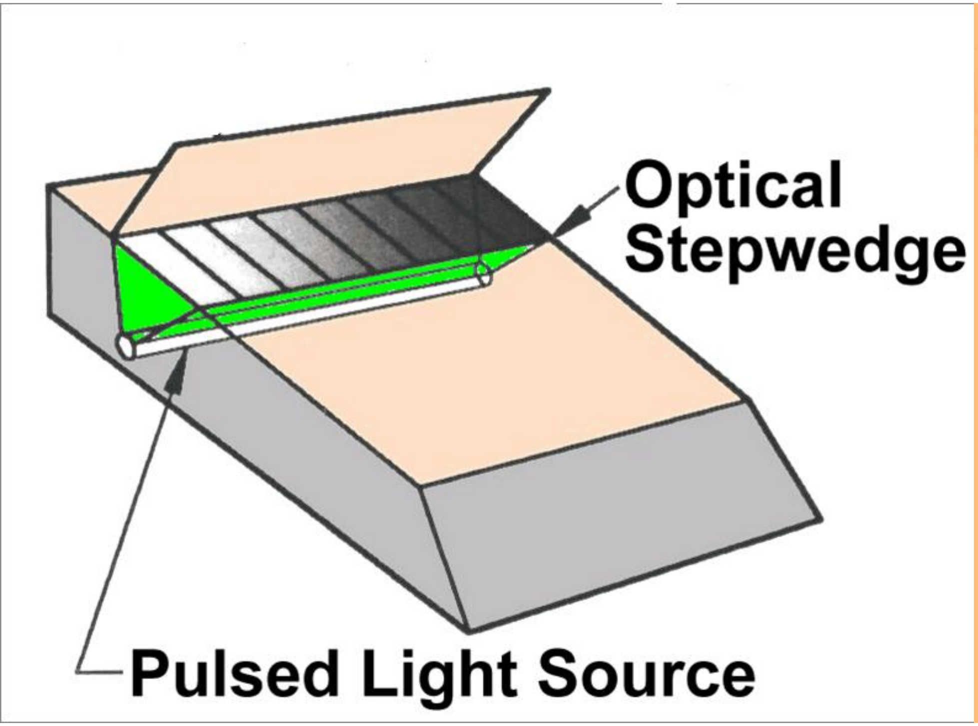
N.B:
Detection efficiency : fraction of incident X-ray photons that react with the screen
conversion efficiency = fraction of absorbed X-ray energy that is emitted as light energy

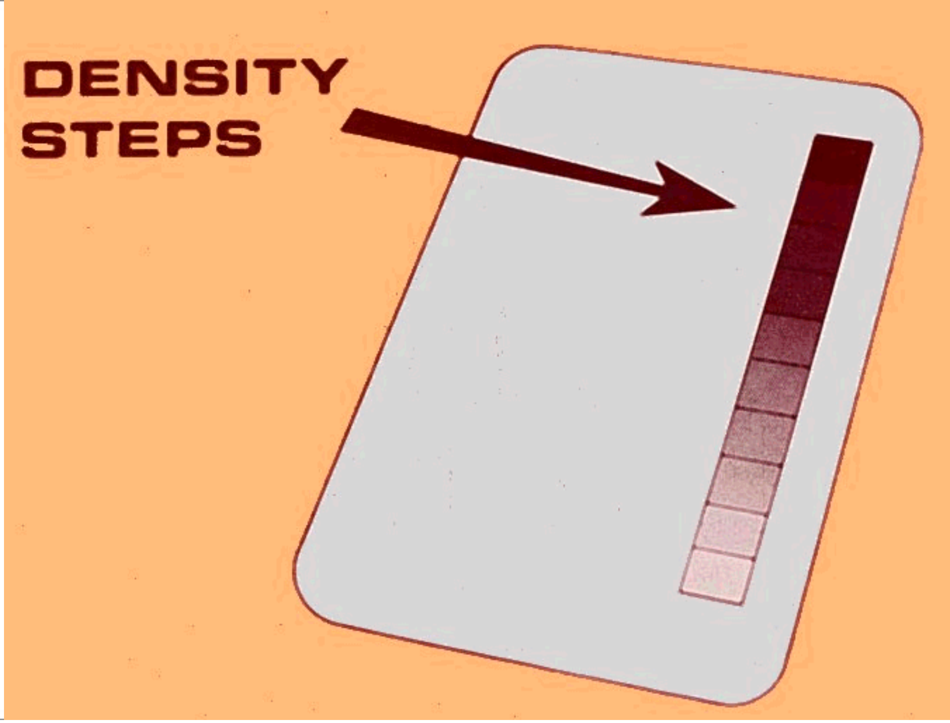
Effects of film processing

Increase developer temperature:

- Increase film speed
- Increase γ initially but above certain temperature recommended by the manufacturer → increase fog → reduce γ

Sensitometer



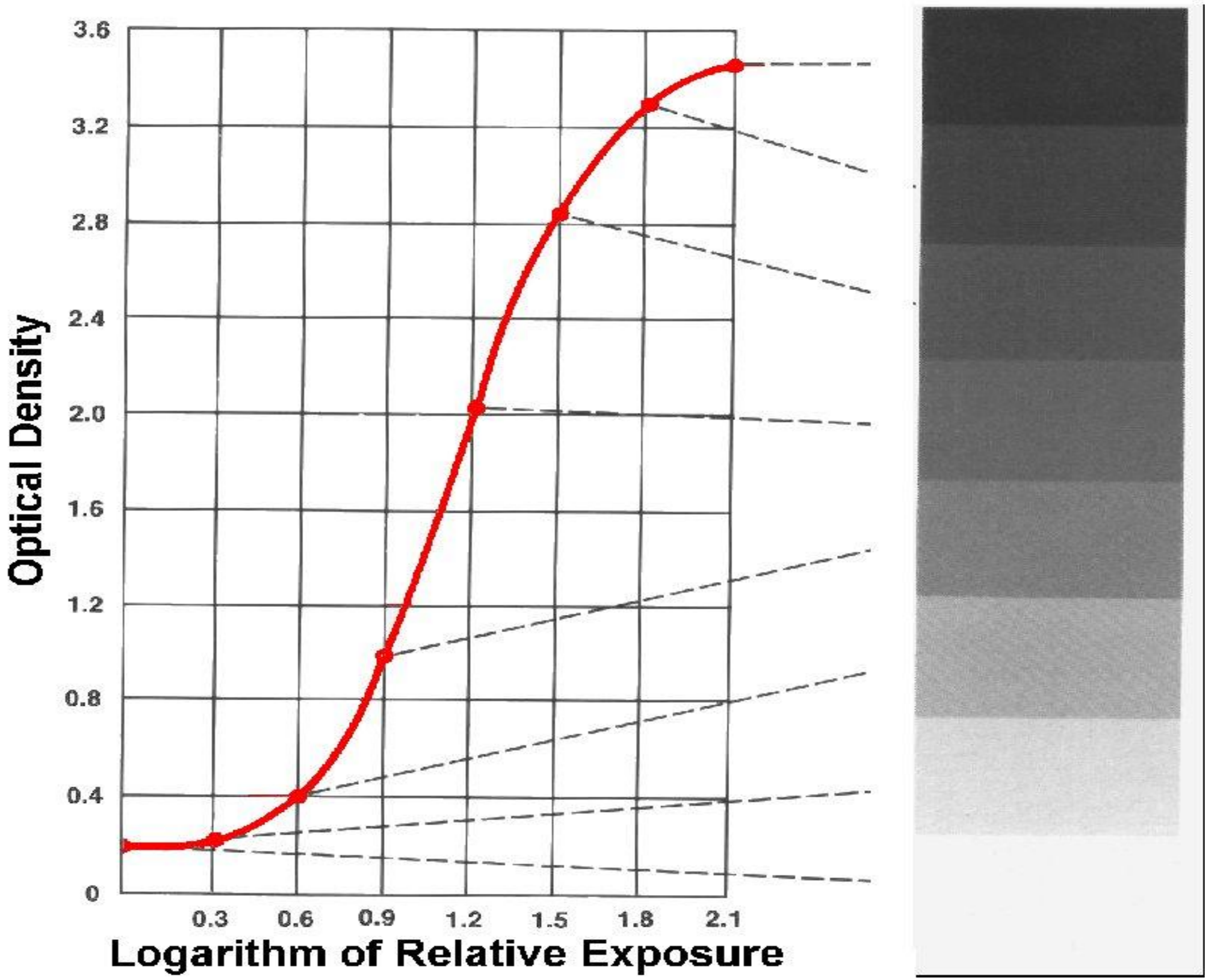


•Consists of

1)Light source

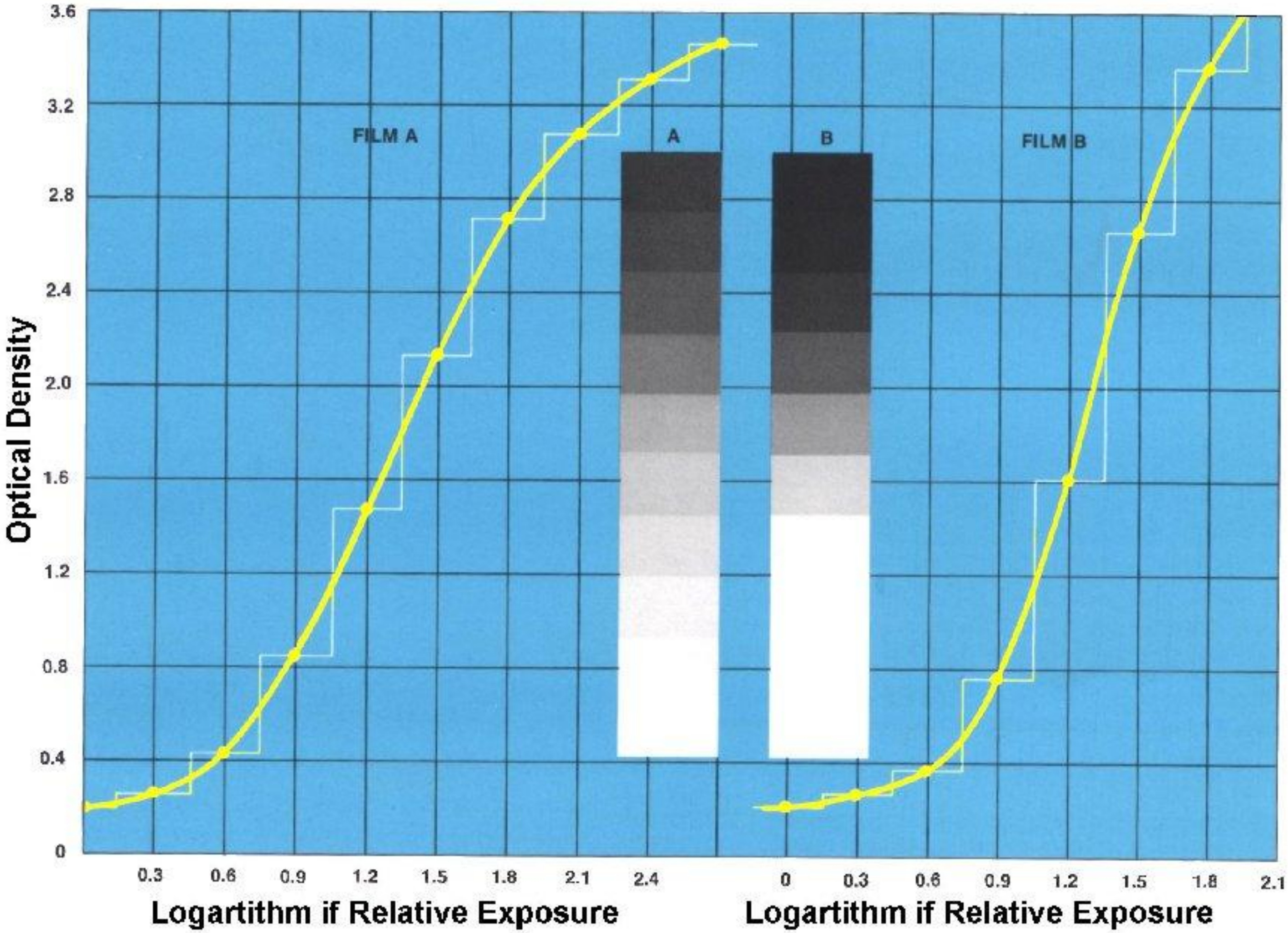
2) array of filters (usually   21 steps)

•After film exposure to light , optical density of each stem is measured by densitometer



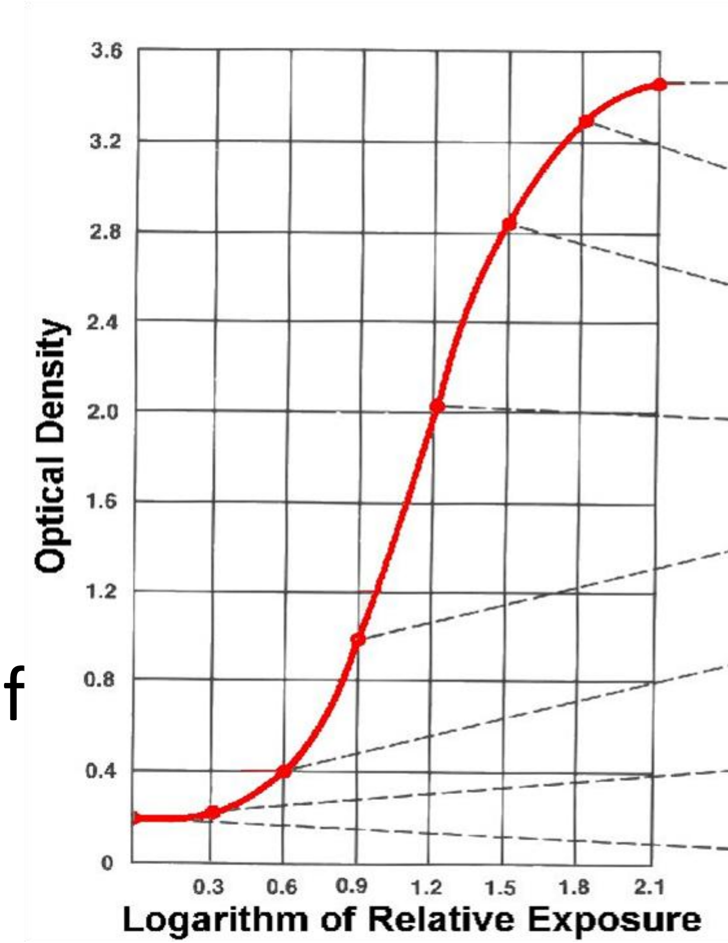
Characteristic curve of the film is then plotted

Sensitometric Curves



Sensitometer as performance test

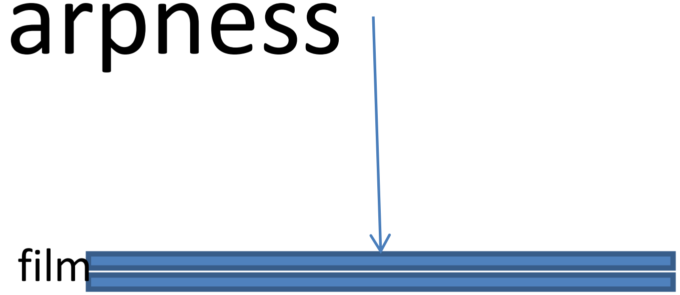
- 1)To measure the fog degree (and so the processing performance): measure the density at the least exposed step
- 2) to measure film speed: determine at which exposure resulted in density of 1
- 3)to measure the contrast : slope of the curve (at density of 1 and of 2)



- ➢ Less than 10-15% variations are accepted
- ➢ Test must be done daily

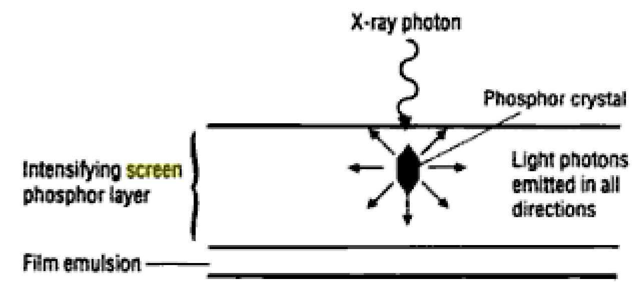
Screen unsharpness and noise

Film screen unsharpness

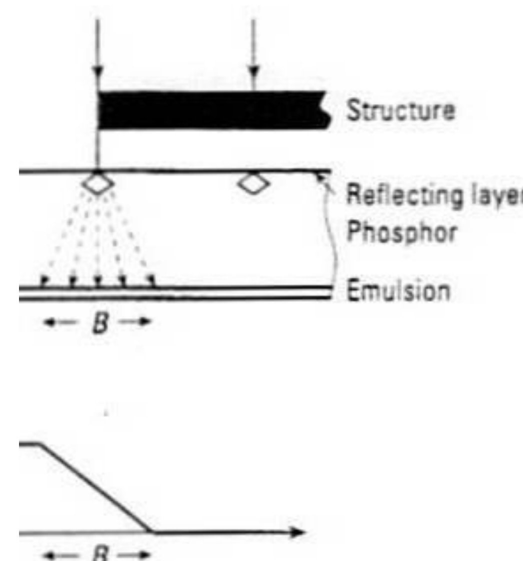


- Without screen: size of a point in the film is limited only by the crystal size
- With screen:

-Light is given out in all directions from point of interaction with the screen

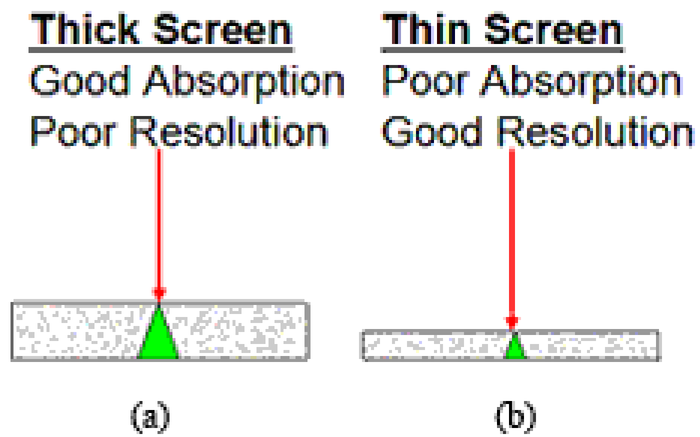


- = screen unsharpness



Factors affecting screen unsharpness

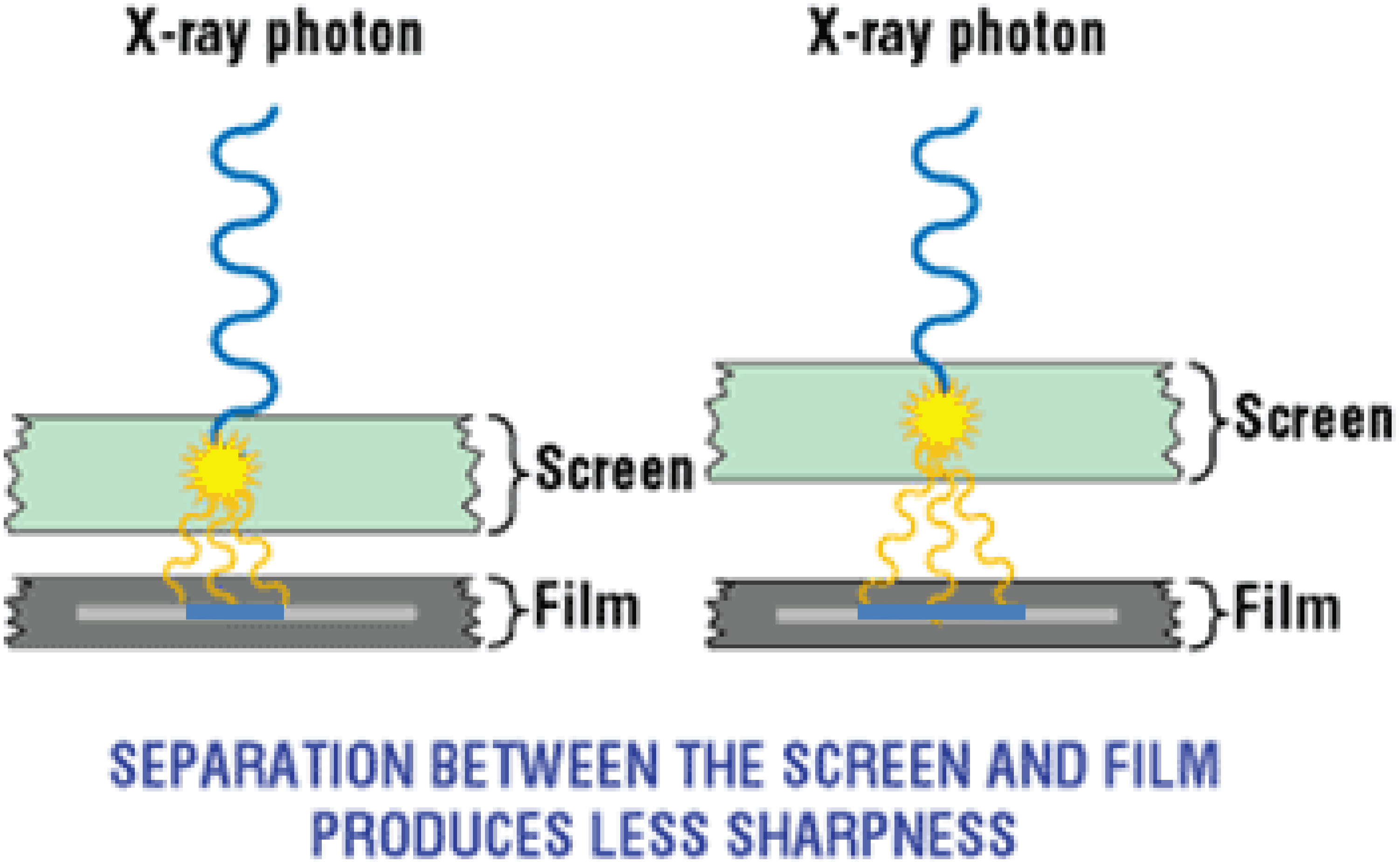
- 1) thickness of the phosphor



↑ phosphor thickness → ↑ screen unsharpness ☹

BUT ↑ phosphor thickness → ↑ screen speed →↓patient's dose ☺

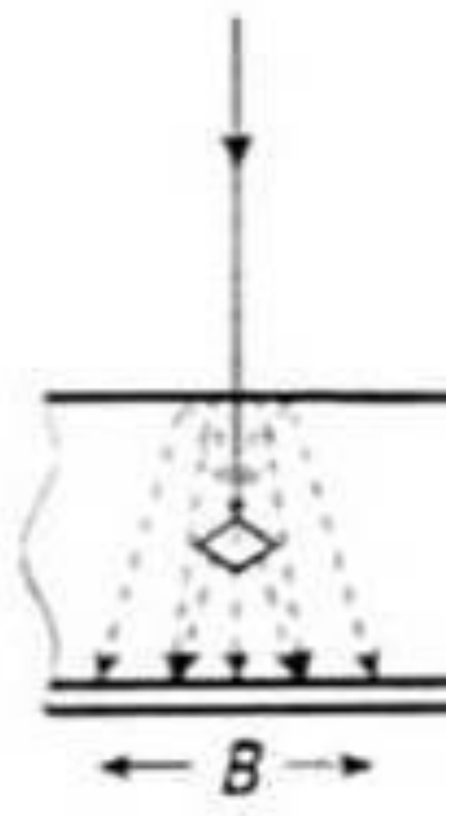
- 2)film screen contact



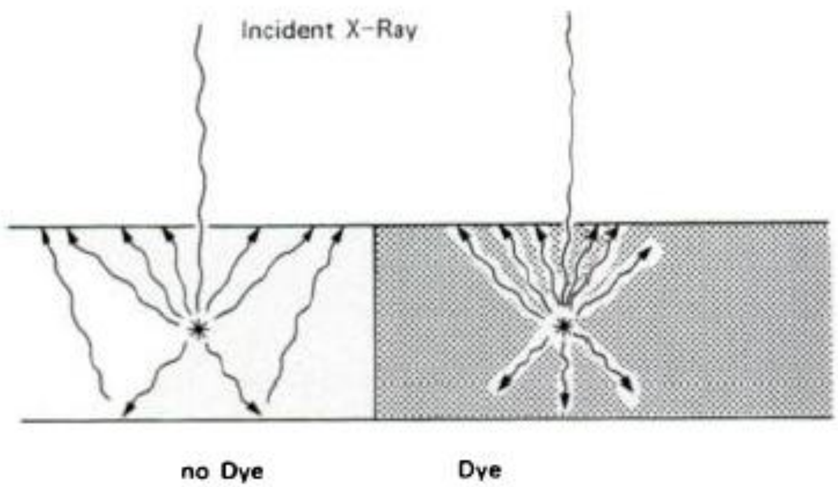
Occur due to cassette damage

- 3)The use of reflective layer

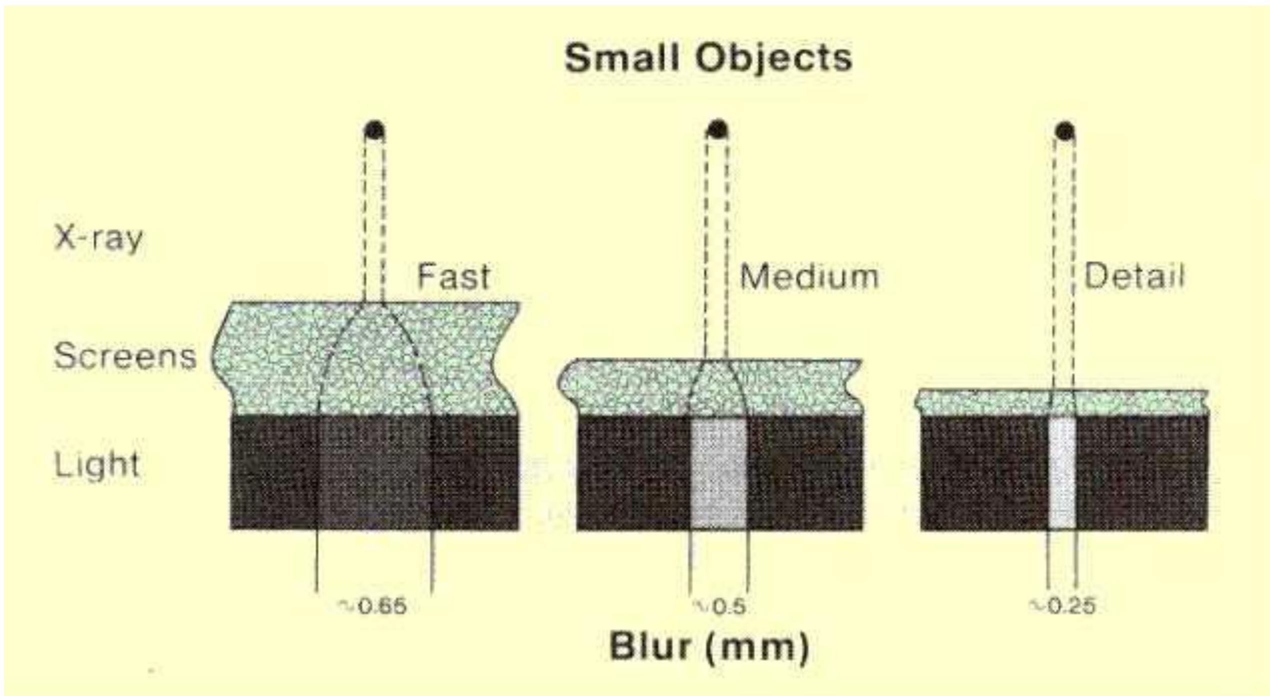
Increase unsharpness , but decrease patient’s dose



- 4) Incorporating color dyes in the phosphor layer:
- Absorbs some light as it pass through the phosphor (more absorption to the photons emitted at wide angle) → decrease unsharpness
- But decrease speed and increase patient dose ☹



Dose or sharpness?

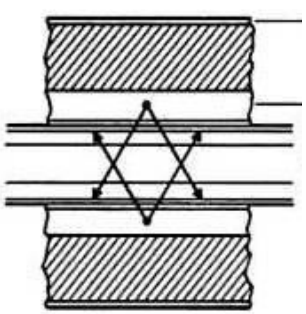


400 speed class (relatively thick phosphor) used to image abdomen and pelvis
100 – 150 speed class (definition screens) used for imaging extremities

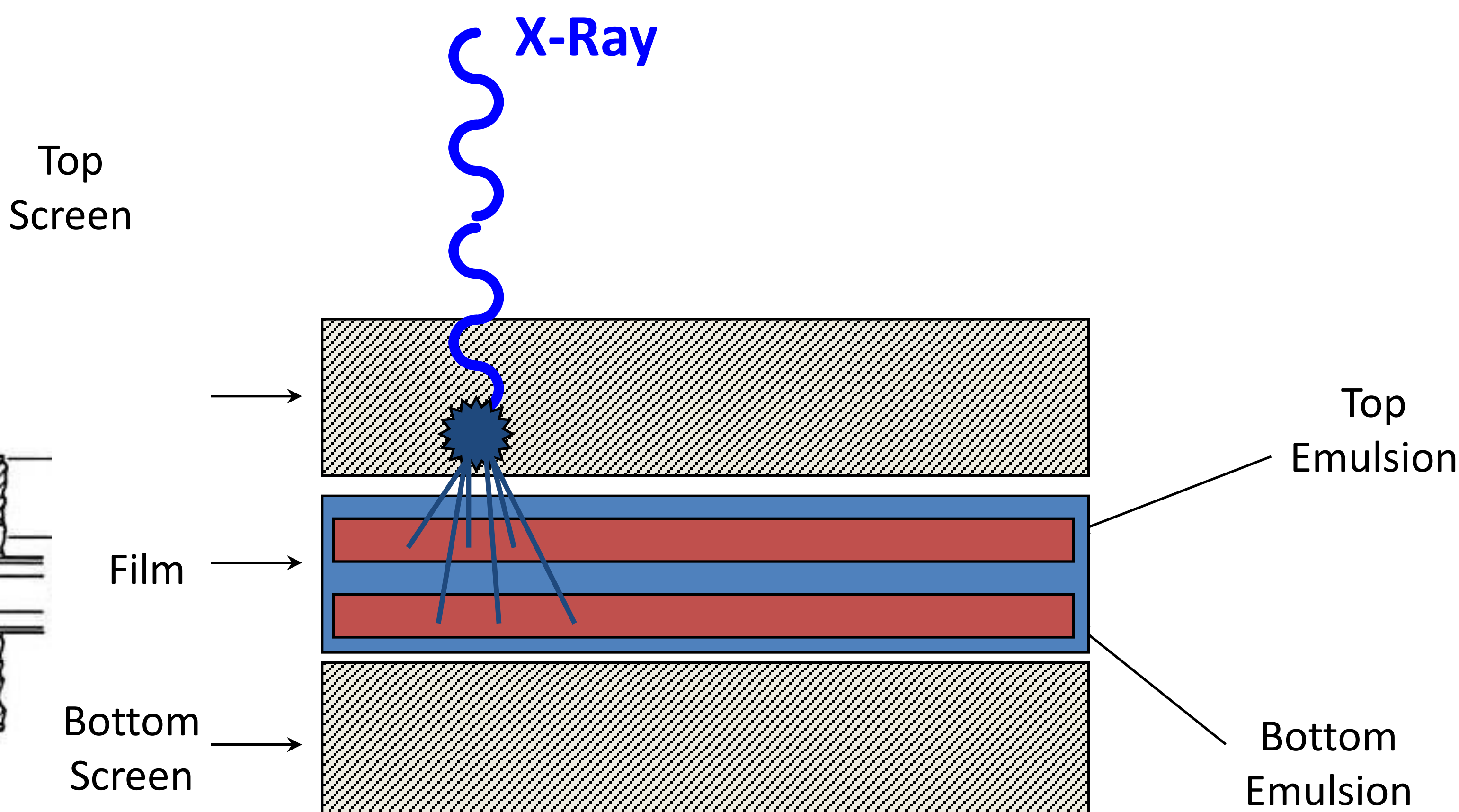
Types of unsharpness seen only in double emulsion films:

1) crossover phenomenon

- Incomplete absorption of light by adjacent emulsion → light from one screen exposes opposite emulsion →light travels further& spreads more → poorer resolution



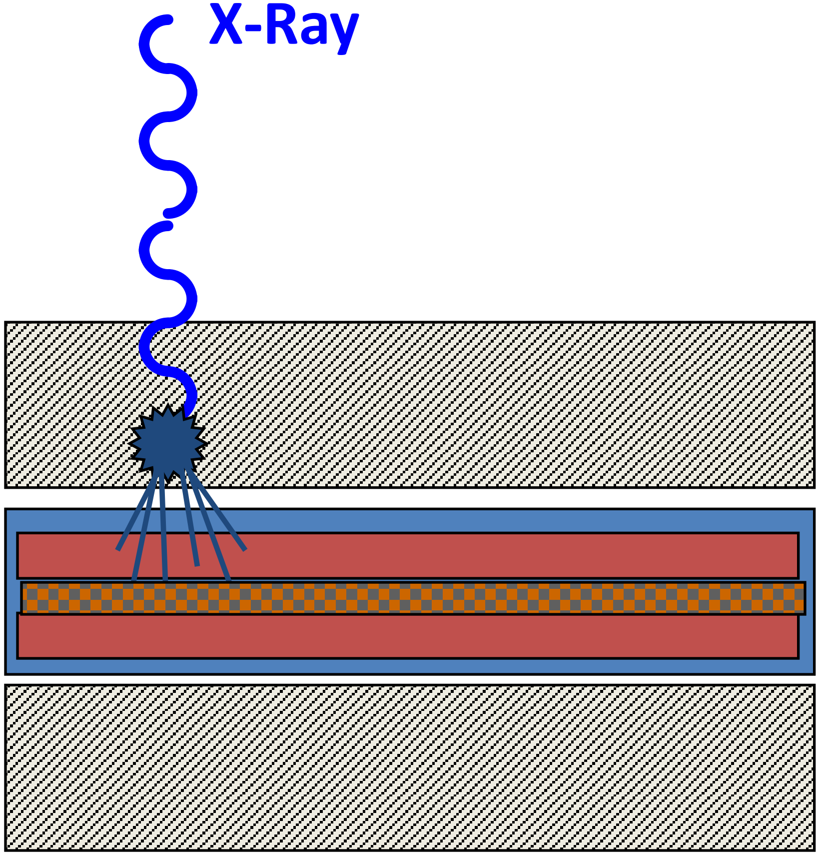
(a)



- Crossover accounts for 25% of film blackening
- A major contributor to the unsharpness

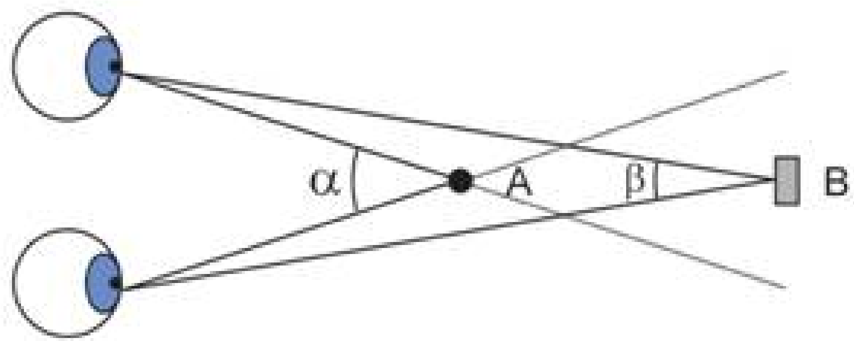
Crossover Reduction

- use light-absorbing dye on film base
- can reduce crossover but also reduces system speed by up to 40%



2) Parallax phenomenon :

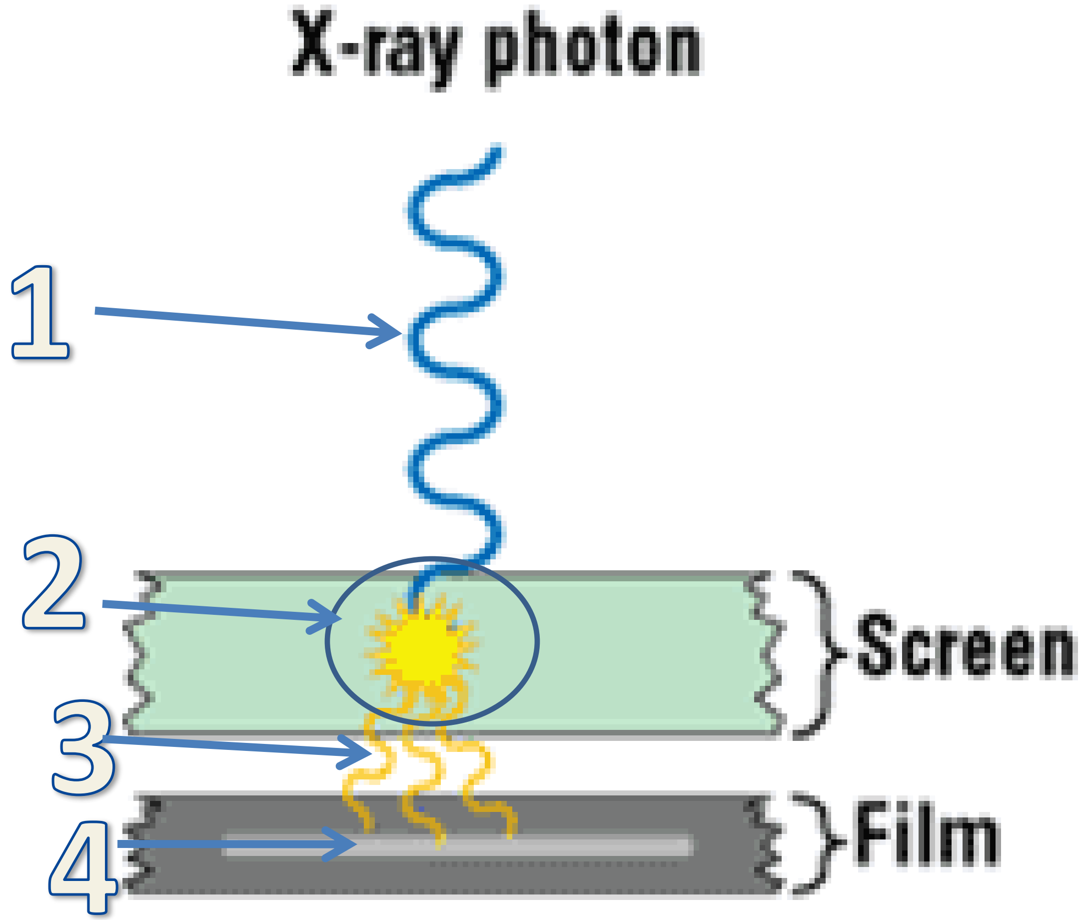
- There is an image in both emulsions, separated by the film base
- If the film is looked at from an angle, these two images do not overlap exactly causing parallax unsharpness.
- Its influence to total image unsharpness is negligible.



Screen and noise

The ***only*** factor that determine the image noise is:

number of X-ray photons absorbed to form the image



- 1) effect of using screen on the noise:

Using screen

Incident 100 x-ray photons

↓ *30% absorption*

30 x–ray photons absorbed

↓ *1:600 intensification*

18000 light photons

↓ *½ of light photons reach the film*

9000 photons reach the film

↓ *1% efficiency in production of latent image*

90 latent image

Not using screen

Incident 4500 x-ray photons

↓ *2% absorption*

90 x-ray photons absorbed

↓ *100% efficiency in production of latent image*

90 latent image

This means that screen increased the noise by the factor of ……………………, while decreased the dose by factor of ……………………..

2) effect of increasing phosphor absorption efficiency:

how?

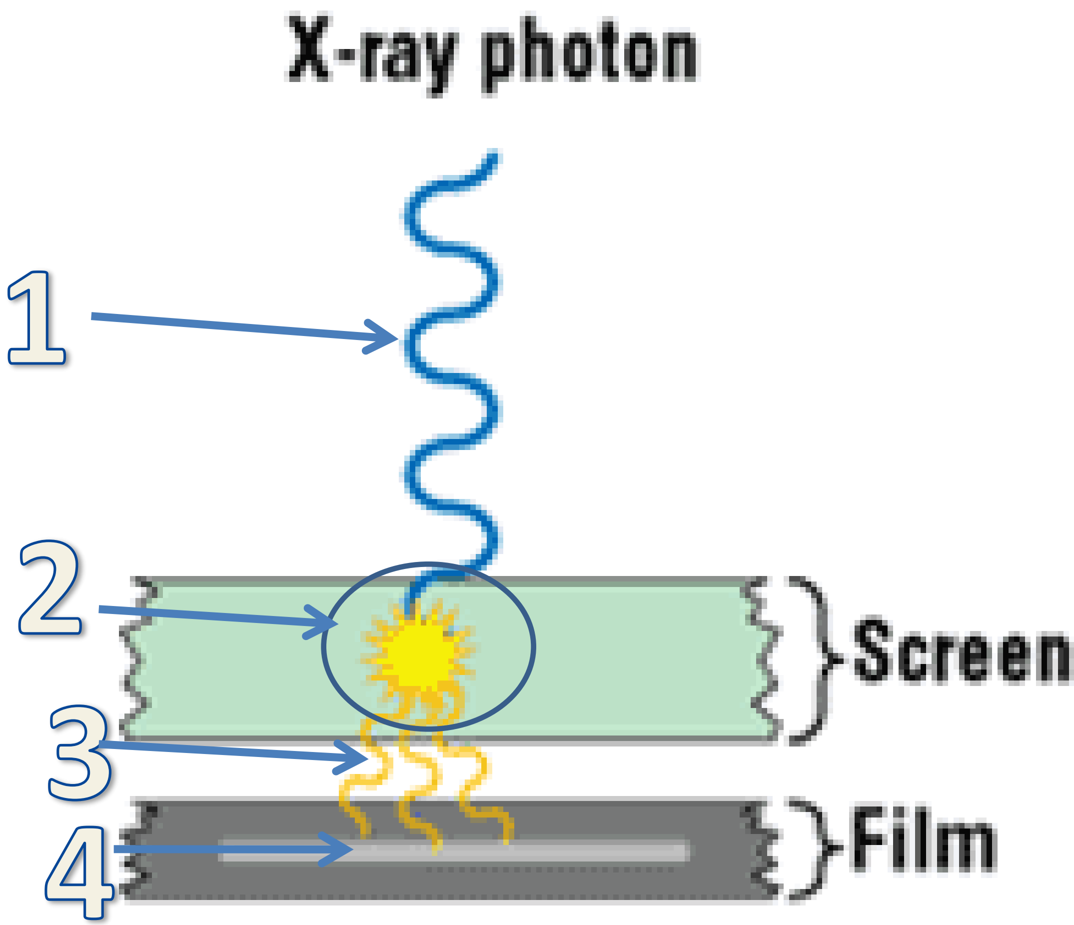
A-By changing phosphor : using rare earth screens

B- by using thicker phosphor

- to reach the same film density:

we can decrease the dose with no effect on the number of X-ray photons absorbed

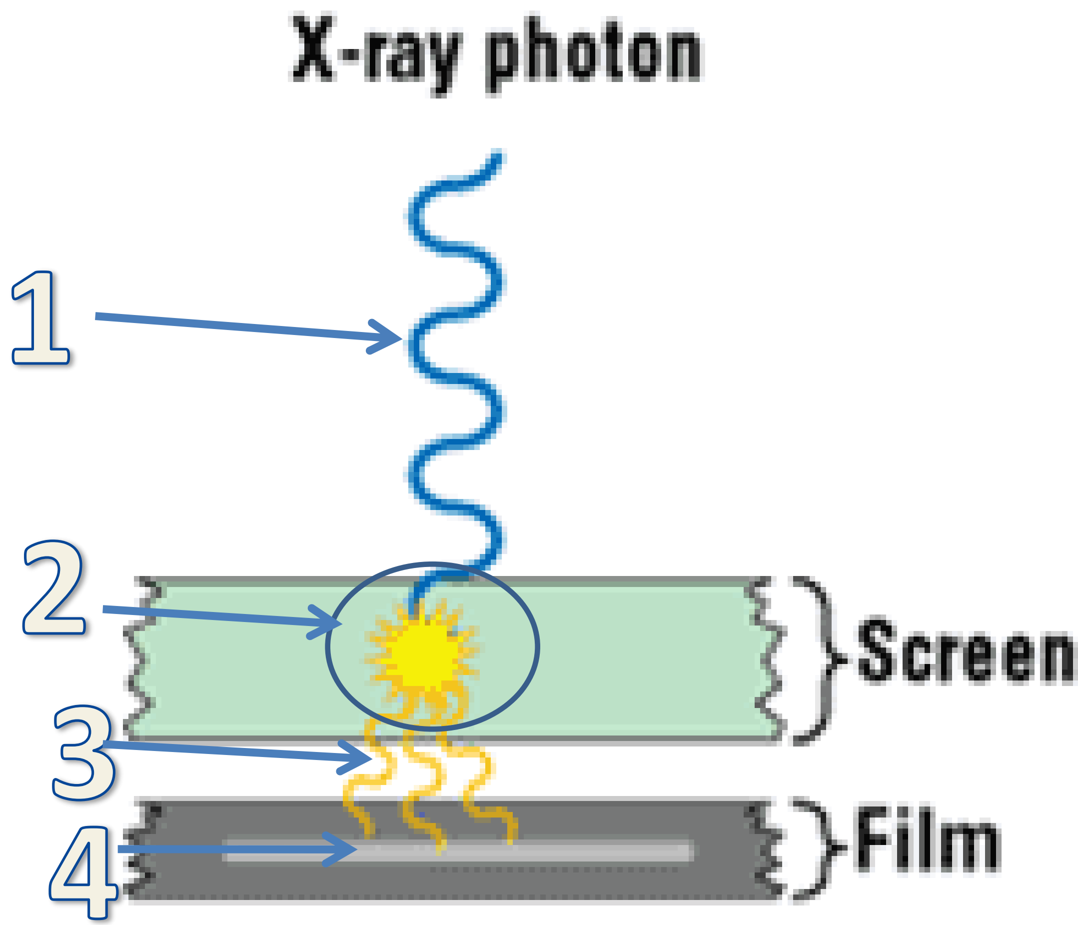
→ decrease the dose with no change of the noise



3)Effect of increasing phosphor conversion efficiency: How?

- Only by changing phosphor : using rare earth screens

to reach the same film density:
we can decrease the dose BUT the number of X-ray photons absorbed WILL BE DECREASED
→ decrease the dose with INCREASE of the noise



RESULT:

- changing the phosphor from Rare earth material screens to calcium tungstate will ………………. The noise
- increasing the thickness of the phosphor with no changing its type will ……………….. The noise

Exposure factors and reciprocal law

Exposure factors

<u>mAs</u>

- mA and exposure time is usually combined and used as one factor expressed as mAs.
- mAs determine the radiation quantity, film optical density and patient dose
- mAs does not influence radiation quality.
- Any combination of mA and time that will give the same mAs should provide the same optical density on the film. This is referred to as the **<u>reciprocity law</u>**.

Reciprocity law exception:

- When using screens (film exposed to light) :
- Blackening produced by same mAs in very short or long exposures is less than 1sec. Exposure
- Can be ignored in clinical practice (except with mammo long exposure times)

- **<u>Kv :</u>**

High kv will

1)↓ patient dose

2) ↓ film contrast

3) ↑ exposure latitude (large range of tissues displayed)

4) ↓ mAs

→mAs will be then depend on :

1) factors affecting beam quality (Kv, filtration , waveform)

2)FFD

3)film screen speed

4) Patient and region thickness

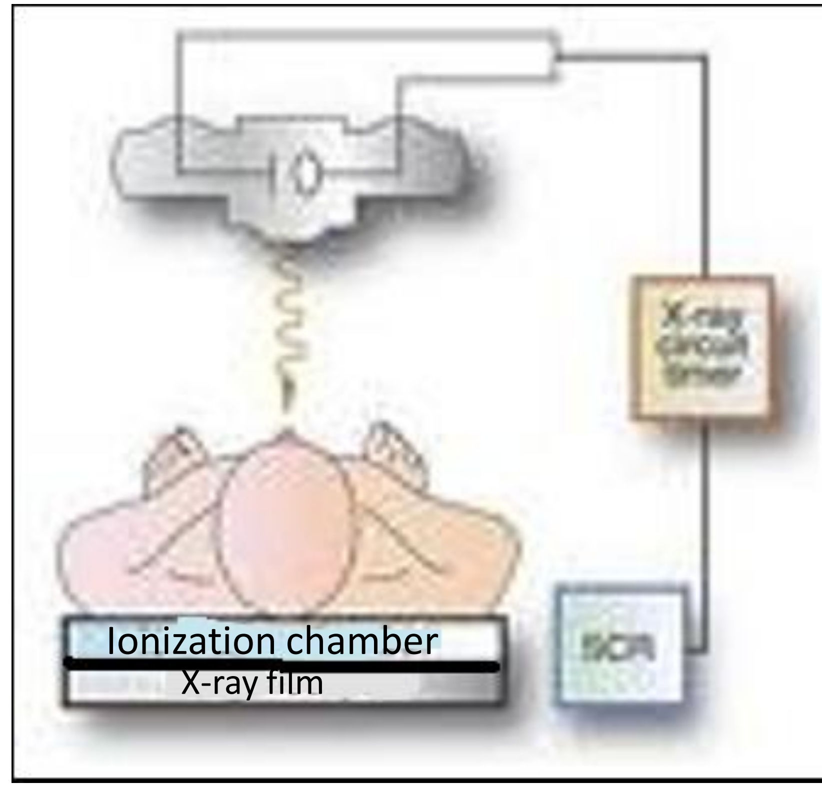
N.B: 1, 2&3 are Equipment related (established for each examination performed in that room)
4: Varies from one patient to another
In very fatty patients requiring very high mAs (unacceptable tube loading and exposure times) → increased kv might be used (with less contrast)

After choosing mAs , The control unit will automatically adjust mA to the maximum permitted according to generator power

→ This will give the operator shortest exposure time to decrease blurring

Automatic exposure control

- **Function:** terminate the exposure automatically when right amount of radiation reaches the film
- **Position :** behind the patient and the grid , infront of the cassette (except in mammo)



- **Composed of:** three parallel plate ionization chambers:

1 and 2: at right and left sides towards patient head

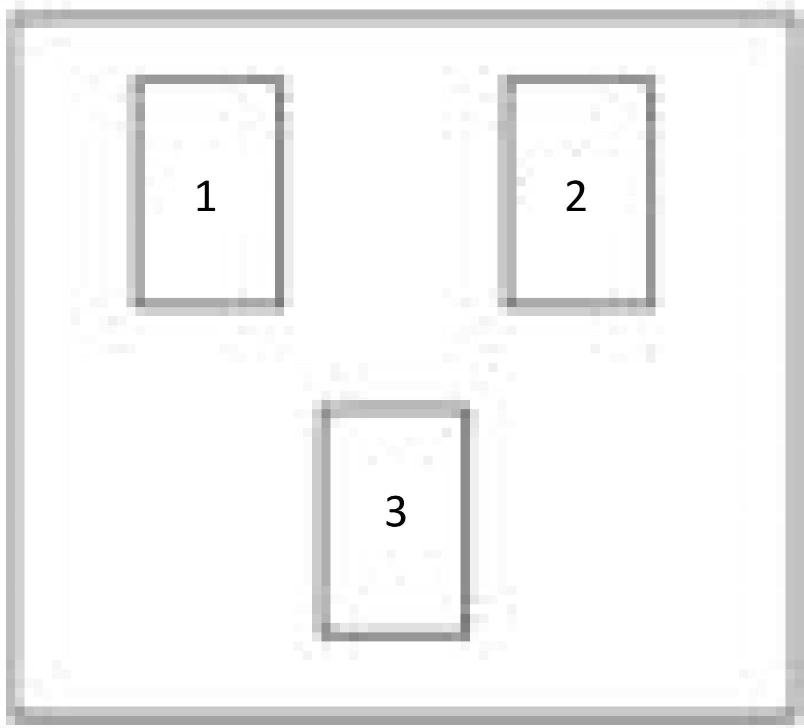
3: at the middle towards patient feet

N.B: Depending on examination type , the operator select which detector would be used

e.g. CXR : 1&2 are used

lumber AP: 3 is used

- Density control is available (to allow production of darker or brighter films



- **Cautions:**

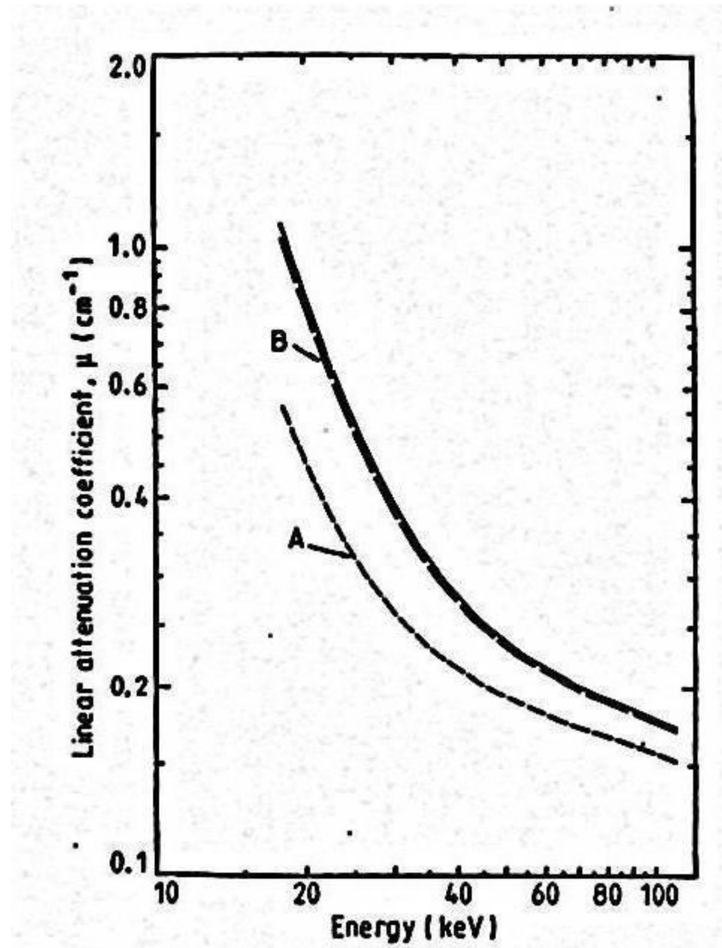
1) Must not significantly attenuate the beam
2) Limited to films taken in the bucky
3) Have fixed geometry → can not be used with all beam sizes (e.g. limited use in pediatrics)

Mammography

Problem: Z of fat and glandular tissue are so close

Solution → to maximize contrast between them

- Use low x-ray energy of about 20-25 kev (according to breast thickness)
- Better to be monoenergetic



A= FAT , B=Glandular tissue

Two target materials for mammography are used:

- Molybdenum :

  Z=42

  Characteristic radiation = 17.4 & 19.6 kev
- rhodium :

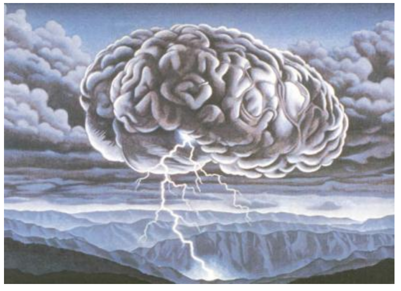
  Z=45

  Characteristic radiation =20.2 & 22.7keV

Advantages: suitable Characteristic radiation energy

Problem: ordinary broad spectrum (bremsstrahlung) is not suitable

BRAIN STORMING

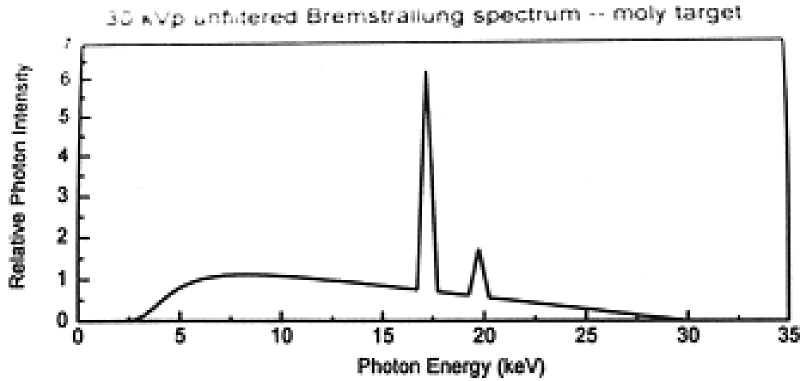


Q. Material is ……………………………… To its own characteristic radiation

Q. We use …………………… window in mammography Tubes (Z=……………….)

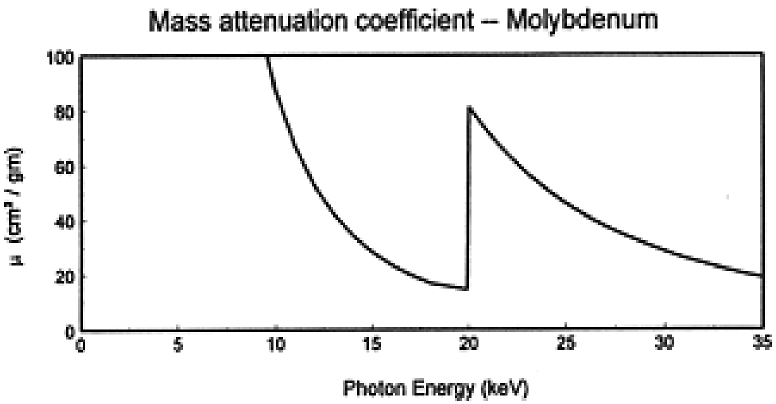
1) Mo-Mo combination

Mo target

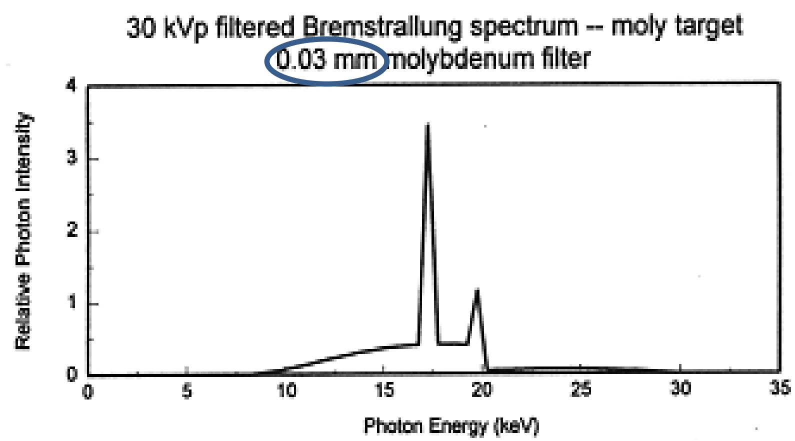


Tube potential = …………

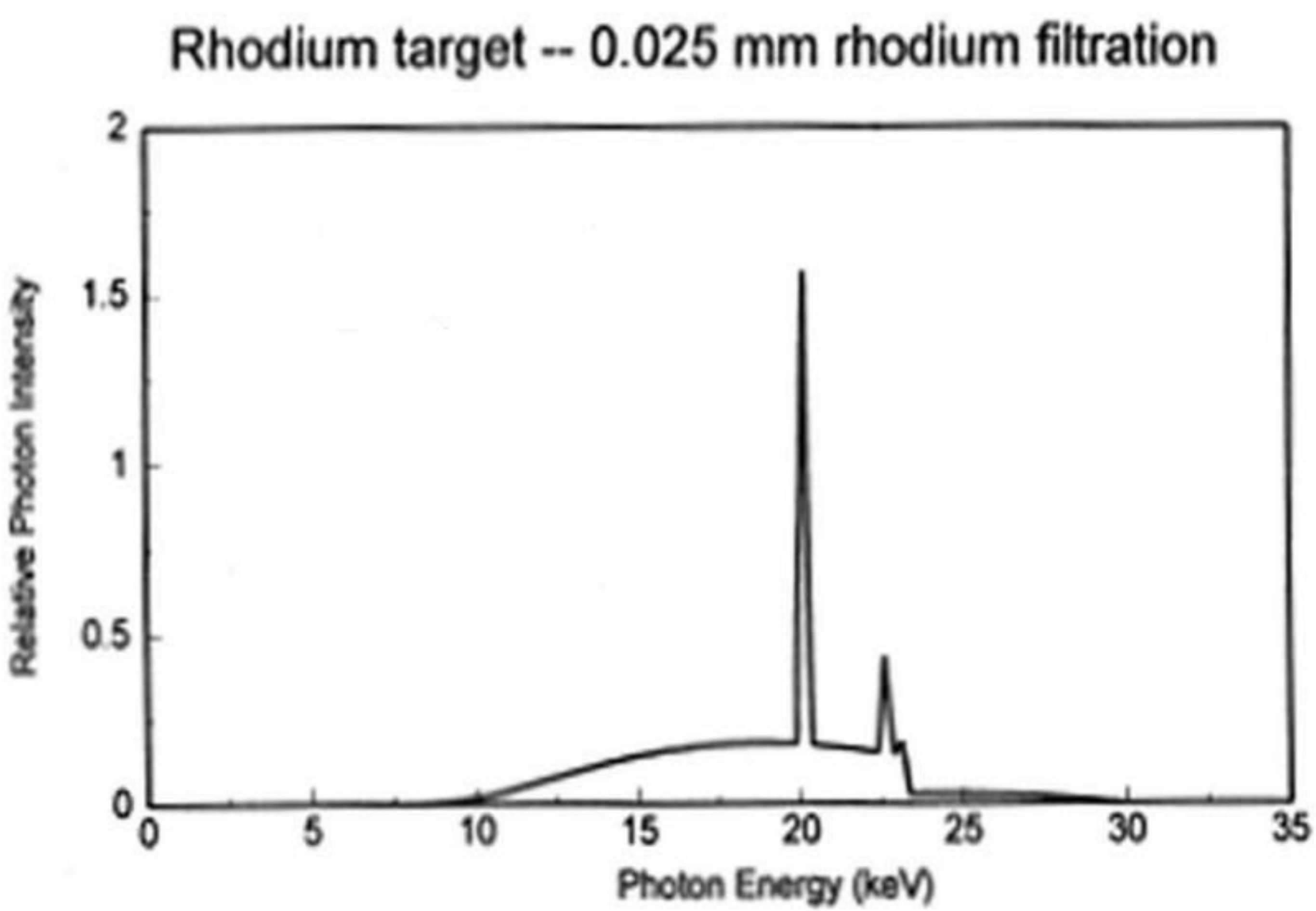
Mo filter



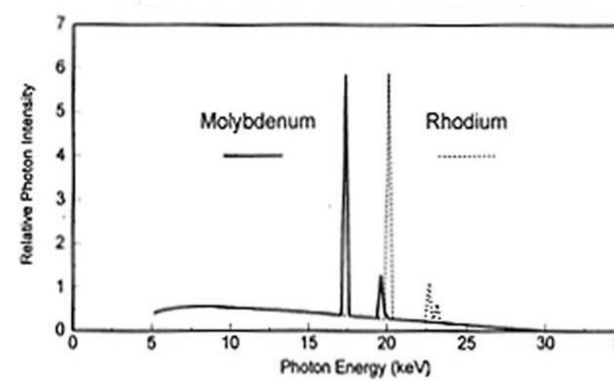
Mo/Mo



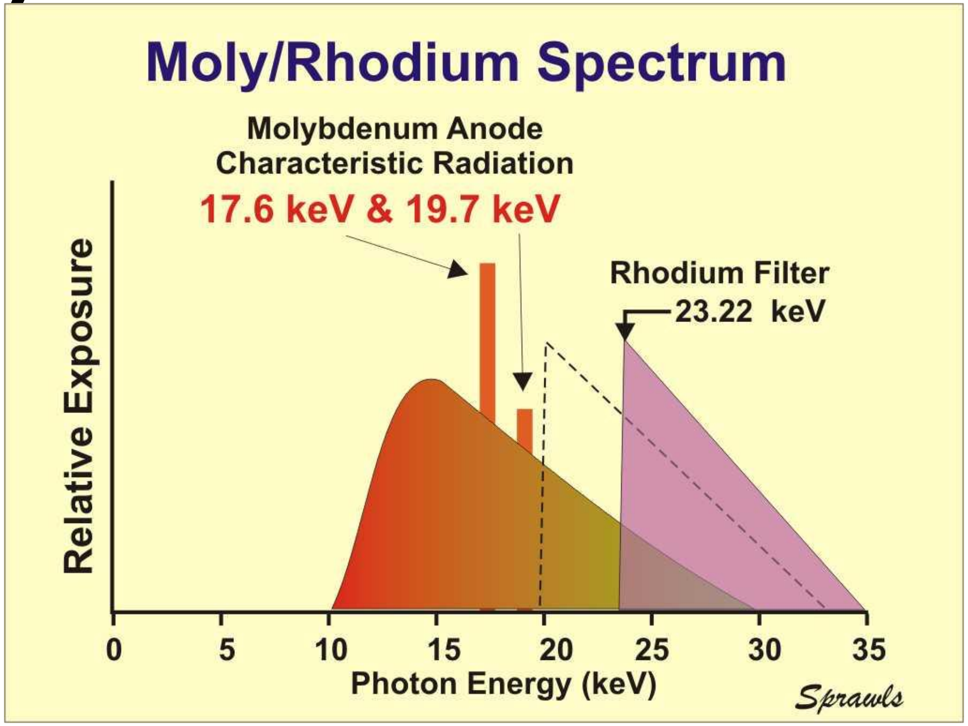
2) Rh-Rh combination

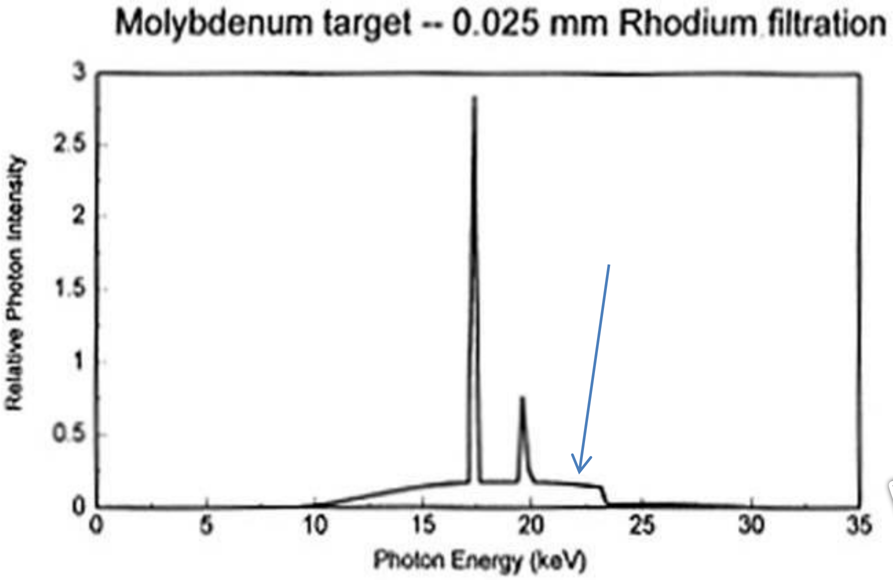


More suitable for thicker breasts (higher characteristic energy)
Used in Tubes designed with dual Mo and Rh targets

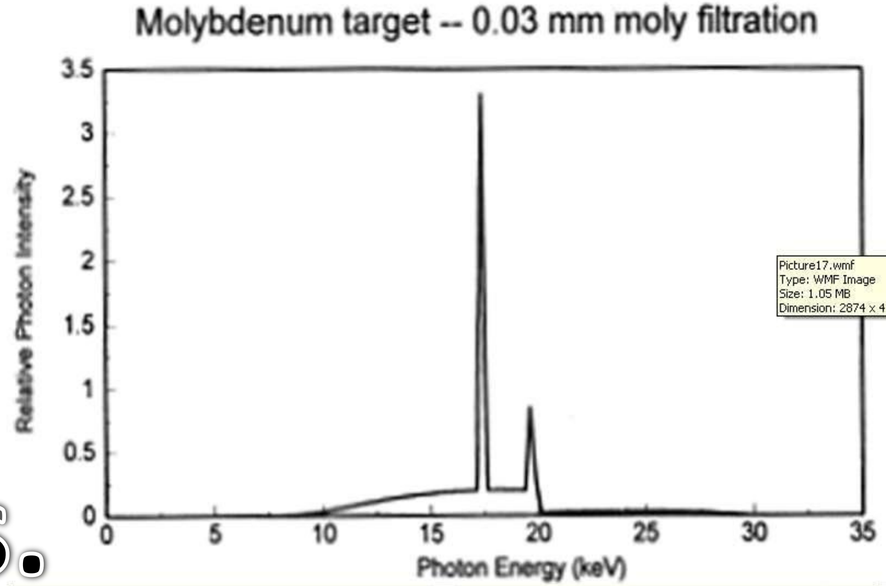


3) Mo-Rh combination





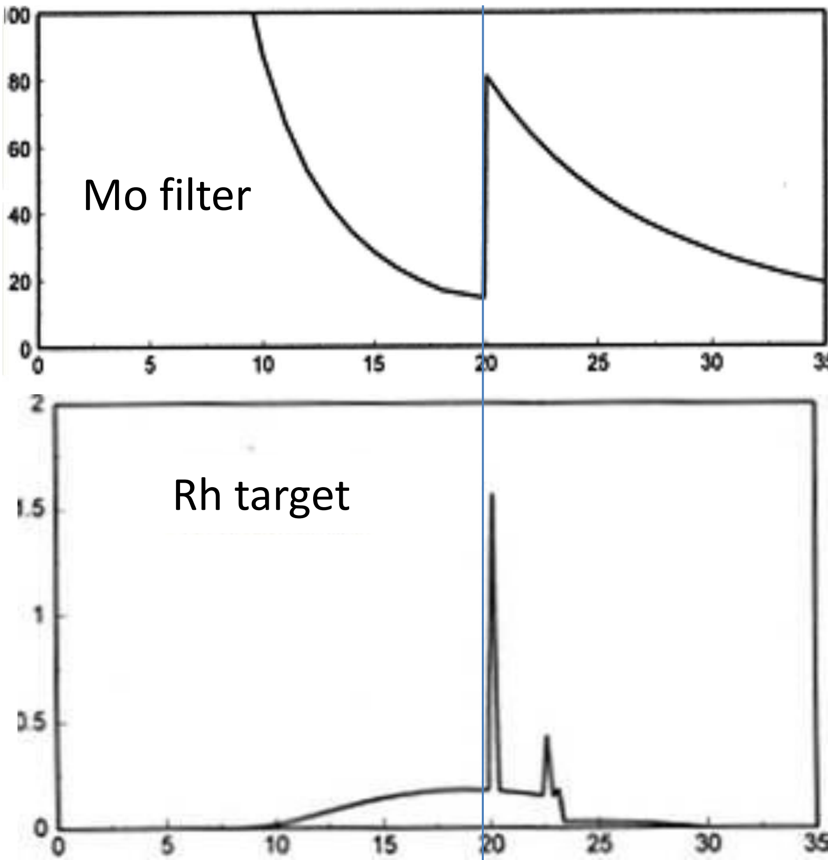
Vs.



3) Mo-Rh combination

- More suitable with thicker breasts
- Used in tubes having Mo target , with selectable filter (Mo or Rh)

- *Q. Why not using Rh-Mo combination?*

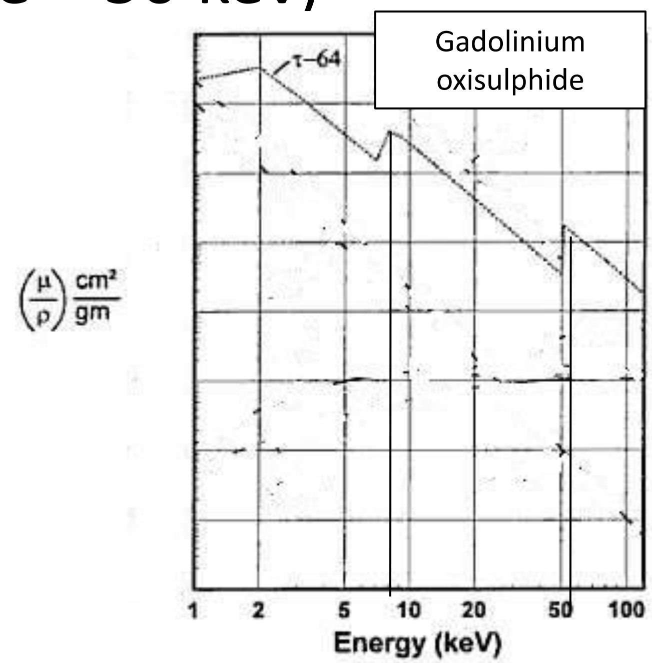


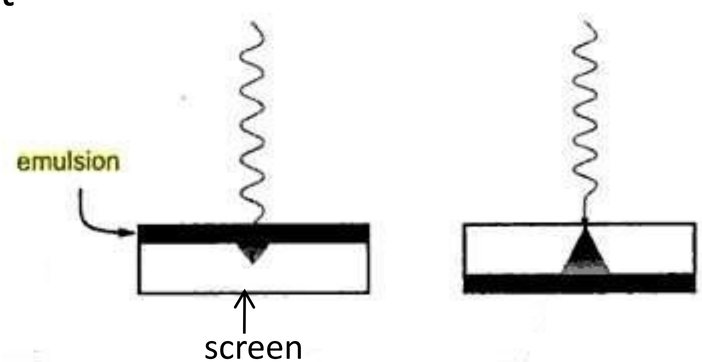
Mammography film screen

1) Used screens are rare earth screens (why?)
2) Mammography spectrum interacts with screen L-shell electrons (rare earth screens k-edge ≈ 50 kev)
3) Thin screens are used to decrease unsharpness (micro-calcifications)

This doesn't affect screen sensitivity (photoelectric α $1/E^3$)

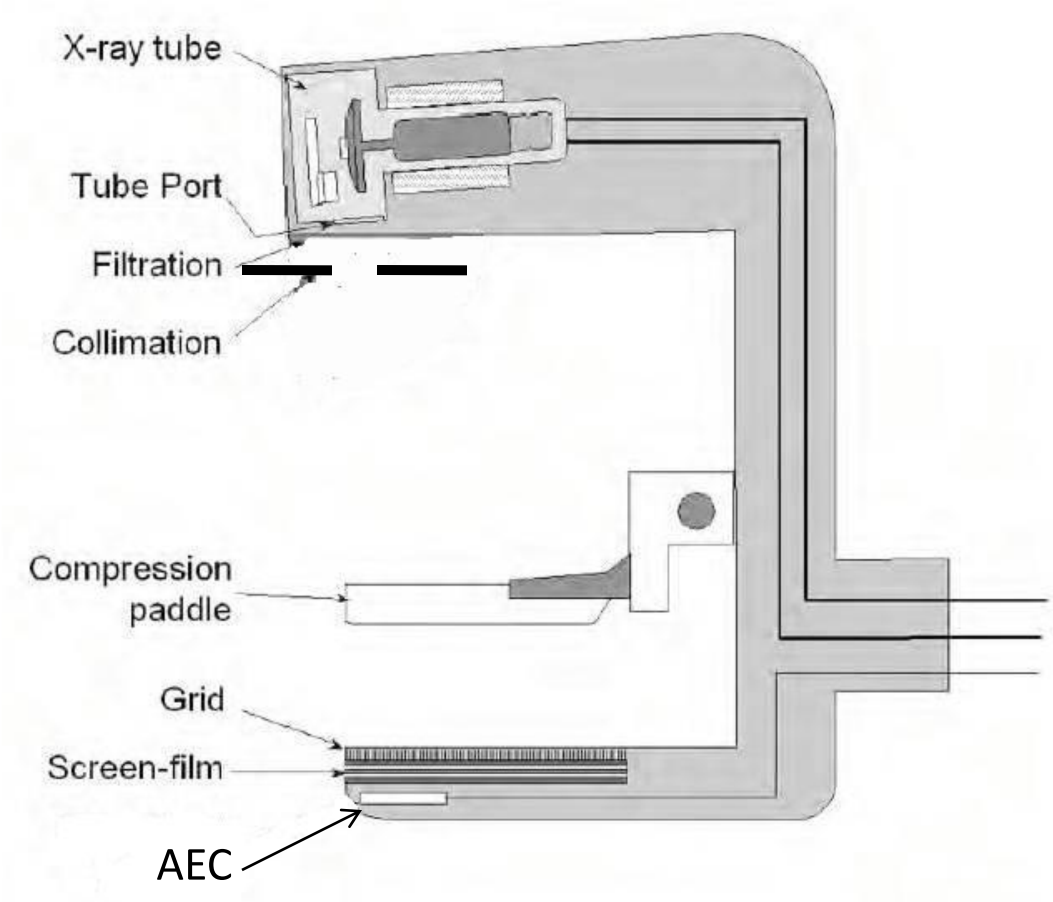
4) single screen and single emulsion film is used (how does this decrease unsharpness?)
5) screen and emulsion is at distal side of the film (interactions are mainly in the part of the screen closest to the film →↓unsharpness)

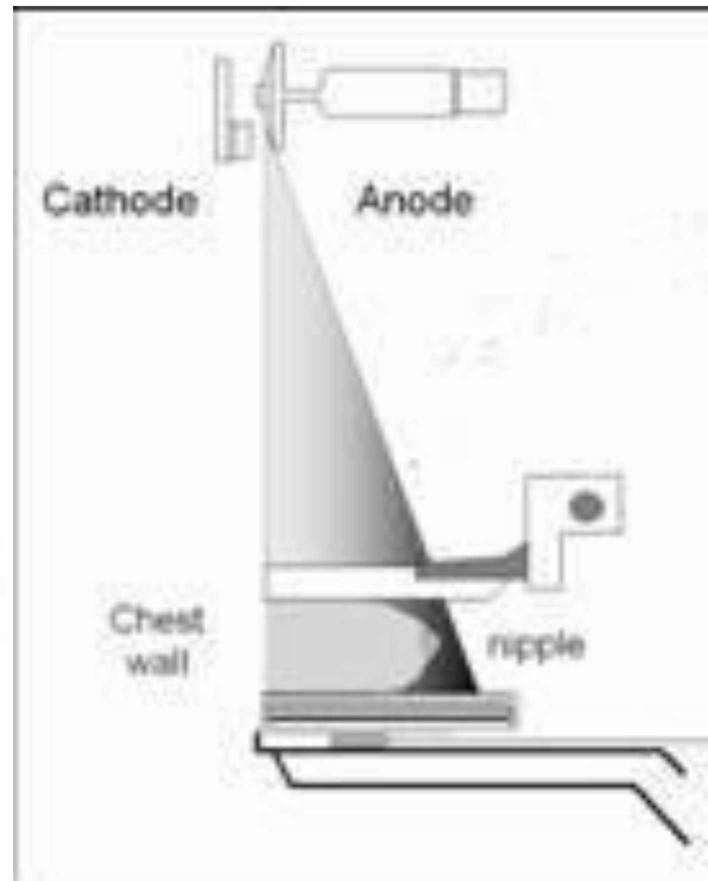




N.B: *Limiting resolution with use of film screen mammography = 15 lp/mm*
Limiting resolution with use of CR mammography = 10 lp/mm

Mammography unit

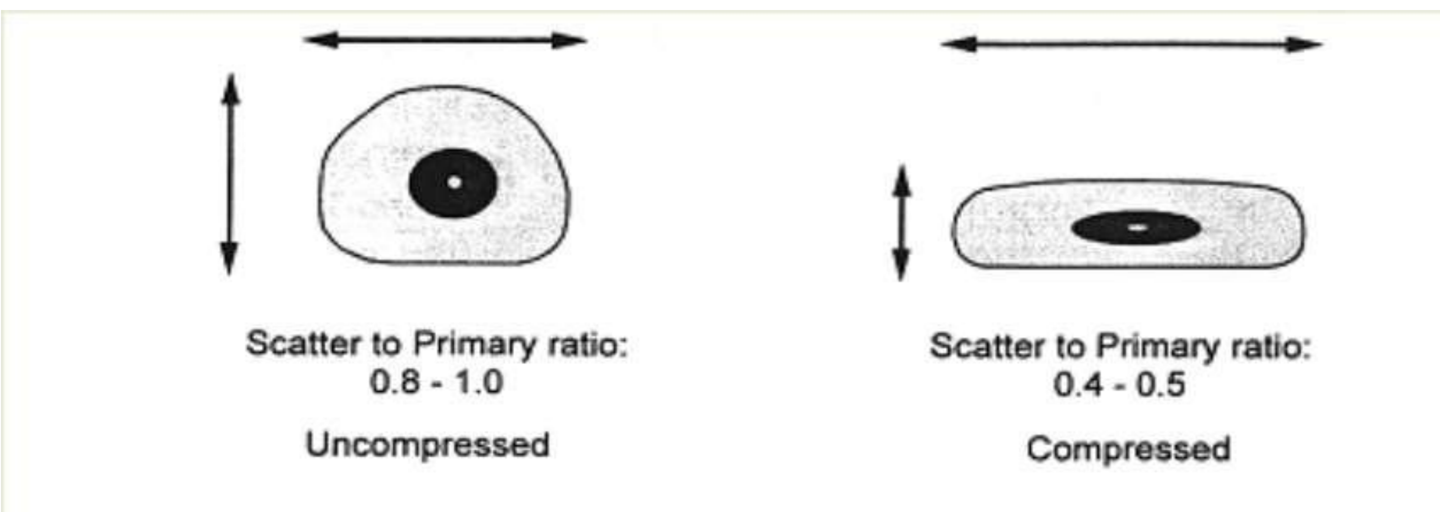




1) Cathode anode axis is perpendicular to chest wall with the cathode on the chest wall side of the patient (why?)
2) Target focus is directly above the chest wall edge
3) Breast is compressed by compression paddle
4) AEC is behind the film cassette (↓dose and avoid superimposition)
5) Moving grid is used (although amount of scatter is low because of ……………………….)

Why Compression ?

- Decrease scatter
- Decreases geometric unsharpness and magnification
- Reduces superposition (separates overlying anatomy)
- Improves uniformity of film density (uniform breast thickness)
- Enables use of high contrast films (more uniform attenuation)
- Patient motion is reduced.
- Radiation dose is decreased
- Reduced beam hardening -> Improved subject contrast



Focal spot ,tube parameters and dose

- Dual focal spot sizes are used : larger = 0.4 mm , and the smaller = 0.1-0.15 (used for magnification)
- Tube current is limited to 100 mA for large focal spot and 40 mA for small focal spot (why?)
- Operating potential = 24-35 kev (why?)
- mean glandular dose = average absorbed dose to the glandular tissue = 1.5-3 mGy / film

Magnification (macroradiology)

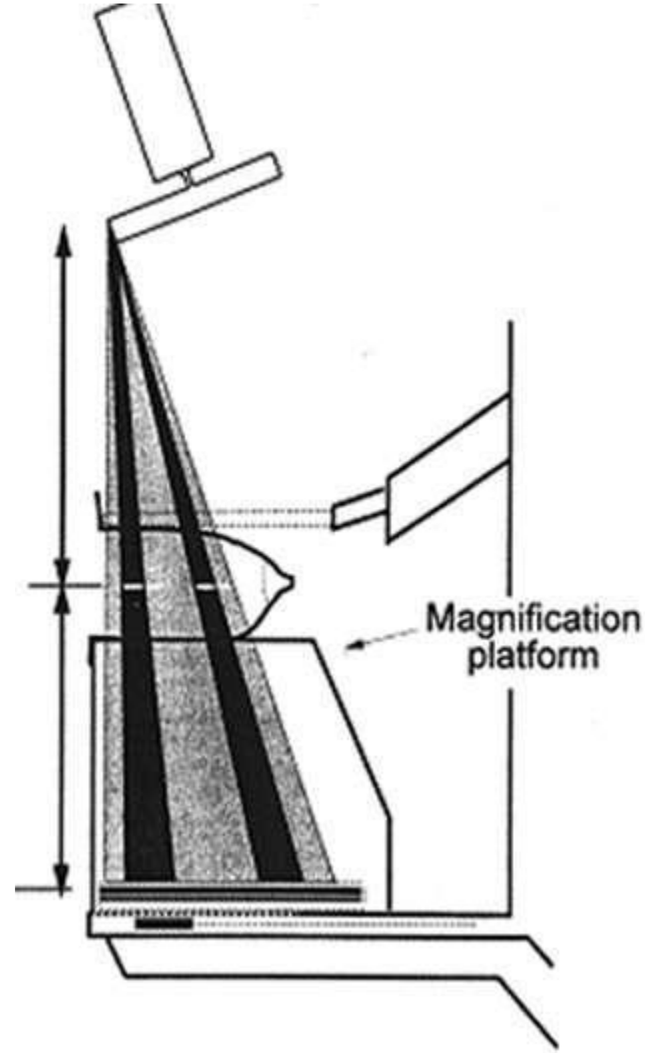
- Now is used only with mammography

•OFD is ↑ so that Platform is at halfway between film and focus (magnification = …………)

•smaller focal spot is used (why?)

•mAs must be increased (inverse square)
-mA rating is limited by small focal spot → exposure time is ↑
-patient's dose is increased

•Will we use grid?



Thank you